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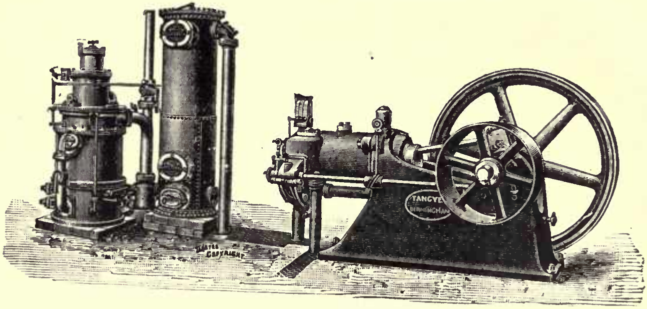

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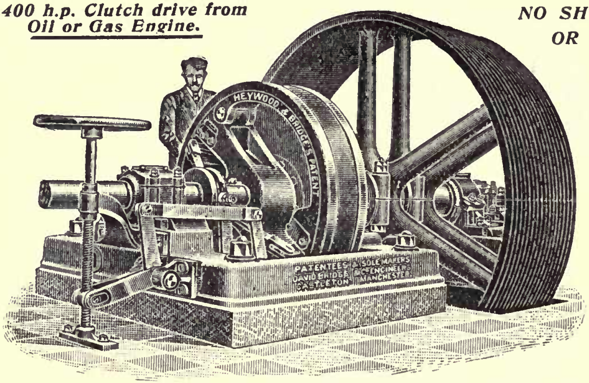

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CONTENTS.

PAGE

LIST OF ILLUSTRATIONS 3
PREFACE 5
INTRODUCTORY 7

PART I.—

Gas Engine versus Electric Motor 9
,, ,, Oil Engine 16
,, ,, Steam Engine 19
The Cost for Gas—Town Gas 24
,, ,, Producer Gas.. 27
,, ,, Up-keep 30
,, ,, Attendance 33
,, ,, Water 35
,, ,, Erection 36
The Powers of Gas Engines 38
The Design of Gas Engines: Cylinders 43
,, ,, ,, ,, Liners 45
,, ,, ,, ,, Piston and Rings 46
,, ,, ,, ,, Crank Shafts 49
,, ,, ,, ,, Fly Wheels 50
,, ,, ,, ,, Governors 52
,, ,, ,, ,, Ignition 55
Hints to Buyers 59
How Gas Engines work 64

PART II.—

Notes on the Gas Connections 68
,, ,, Air ,, ... 73
,, ,, Exhaust ,, ... 75
,, ,, Water ,, ... 79
,, ,, Foundations 82
,, ,, Suitable Sites 86
Hints to Erectors 89

PART III.—

Notes on Starting and Starters.. 95
,, Failures and Defects 100
Hints to Attendants. 107

SUPPLEMENTARY CHAPTER—

Suction Gas Producers 115
INDEX 124

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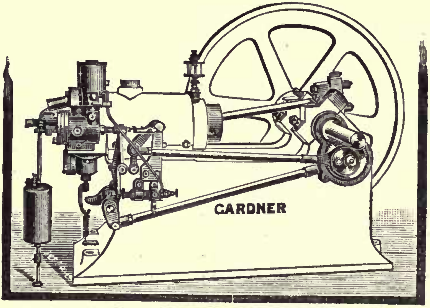

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ILLUSTRATIONS.

PAGE
Tables—Comparison of Working Costs and Capital Expenditure 17, 18
Gas Engine Cylinder and Liner 45
Gas Engine Solid Piston and Rings 47
Ignition Tube (Porcelain) and Fittings 56
Electric Ignition—Magneto with Oscillating Sleeve 58
Indicator Diagram showing Cycle of Operations... 66
The Component Parts of a Gas Engine 67
Gas Engine and Appurtenances Erected 94
"Dowson" "Suction" Gas Producer 119

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PREFACE.

First Edition, Sept., 1903:

THE object of this little book is to explain the advantages, action and application of Gas Engines to those who desire to obtain reliable information on the subject in non-technical language and without close study.

The chapters in Part I. provide answers to questions in the order they would probably occur to a "power" user. The advantages over other motors are detailed, the cost of running, up-keep, attendance and erection are given, and the various terms of power explained. A few notes upon the variations in design of Gas Engines now on the market, and some hints to buyers, complete the portion of the book specially addressed to those who have to make the purchase.

Part II. is written more for the workmen who instal and foremen and others who superintend. It is intended merely to record a few notes that may sometimes serve to "jog" the memory.

Part. III. is for the attendant. It contains a few words about starting, probable failures and defects and their remedies, and some hints that may prove useful.

While disclaiming any technical value, it is hoped that this little volume will prove of service to the many persons who, at some time or another, have to consider the adoption of motive power and desire to know what the installation of a Gas Engine entails.

W. A. T.

Fourth Edition, September, 1907:

The first three chapters have been entirely rewritten and other slight variations made in the text.

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INTRODUCTORY.

THE great progress that has been made in Gas Engine building of late years has quite dispelled any doubts about their reliability. All mysteries have vanished, and they are now worthy of as much confidence as steam engines have hitherto enjoyed.

The great majority of Gas Engines sold are of the sizes up to 100 Brake H.P., and it is in connection with single cylinder engines of this class that this book is written. One hundred Brake H.P. does not express the safe limits of power for Gas Engines by any means. Single cylinder engines up to 250 B.H.P. have been made, double cylinder and quadruple cylinder engines are made to develop up to 5,400 H.P.

The recent progress in the manufacture of Gas making plants for power purposes, upon the well-known "Dowson" process and also upon the "Suction" principle, has without doubt opened up a wider field for these useful motors. By the invention of Mr. J. Emerson Dowson and the improvements since effected, the Gas Engine has become a serious rival to the Steam Engine. The conversion of bituminous small coal into combustible Gas and the simultaneous recovery therefrom of sulphate of ammonia, under Dr. Ludwig Mond's patents, has further increased the field, and, at the present day, manufacturers cannot afford to neglect consideration of Gas motors when requiring new "prime movers." The economy, reliability and advantages of Gas Engines are now beyond question even for large powers.

A few notes are given at the end of the book describing one of the " Suction " plants upon the market. A separate handbook* deals with gas-producers generally, illustrating and comparing different types—British and Continental—by means of which, it is hoped, some useful and reliable information will be imparted to those whose technical knowledge is slight but whose responsibilities demand the careful consideration of up-to-date methods of power production.

Some of the illustrations appearing in these pages are specially prepared for this work, but others have been reproduced by the kind permission of various manufacturers, to whom the Author expresses his appreciation of their courtesy.

---

* "Gas Producers for Power Purposes," published by Percival Marshall and Co., 26-29, Poppin's Court, Fleet Street, London, 1s. net, postage 2d.

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PART I.

CHAPTER I.

THE RELATIVE ADVANTAGES OF GAS ENGINES AND ELECTRIC MOTORS.

IN considering the relative advantages of electric motors and Gas engines it is, first of all perhaps, advisable to realise the advantages that electrical driving may possess and then to compare the performances of a Gas engine.

There cannot be any doubt that the ability of being able to set any one machine at work at any time without reference to any other machine or process is a very desirable thing, but practical considerations rarely allow such a system being adopted. First of all each electric motor thus fitted must be capable of giving out the maximum amount of power ever demanded by the machine, and this not always a simple task. An electric motor has no reservoir of power such as is provided by a Gas engine flywheel, to overcome instantaneous, but heavy, demands, and therefore although the machines to be driven may require normally but a small amount of power yet the motor has to be large enough to cope with the maximum power which may only be demanded for a comparatively short period of time.

Electrical driving of isolated machines is therefore an expensive matter, not only because it costs more for a number of small motors than for a lesser number of large ones of equal total power, but because individual driving necessitates the larger number of small motors to give greater aggregate power than when machines to be driven are grouped together. It is often spoken of as an advantage that an electric motor will continue to deal with overloads until it gets nearly red hot, while a Gas engine will slow up under similar conditions. This, however, instead of being an advantage for electric motors, is really a disadvantage, as great damage can be done if continued overloads cause a breakdown in the insulation. Gas engines protect themselves and refuse to be overloaded.

Grouping of machines allows the expense of electric power installations to be somewhat lessened, but then the advantages of electrical driving have been greatly curtailed, it being necessary to set the motor to work driving the whole of the transmission gear whenever only one machine is actually required to be put into operation.

Apart from the cost of installation there is the question of running costs, and here it is that Gas engines show to the greatest advantage. So much so that it frequently pays a power user to generate his own electricity by means of a Gas engine and dynamo, and to use the current for supplying a number of motors in different departments of his works.

Indeed it is advisable for a power user to compare Gas engines and electric motors on running costs alone, apart from capital outlay, and, to avoid confusing a power user with a too technical comparison, it is proposed to deal with the subject upon the basis of running costs only.

Dealing first with those installations which are supplied with current from public supply mains, it will be found that the rate at which current is supplied will vary with the amount of current consumed. The largest consumer usually considers that he should be charged at lowest rates, but this is never so in practice, because, having no reservoir of current to fall back upon, electricity undertakings give preference to those users of their current who take the largest proportion of current spread over a number of hours.

Supposing, for instance, a factory has a number of heavy tools to be operated which work intermittently, and that a second factory has a number of small tools which are worked continuously. The electric supply companies will give a better rate to the second than to the first, because the amount of current used bears a higher relation to the maximum demand, and is steadily and uniformly used during the whole time of operation. In the first factory it would be quite possible for the same or even larger amount of current to be used up in a fraction of the time that the second factory would use it. But, clearly, the first factory would create more disturbances in the generating stations, and would therefore be less desirable customers. They are therefore charged at higher rates.

The electricity supply companies quote rates entirely governed upon the load factor principle. Any machines such as fans, etc., which, when working are always at the maximum output, are given the lowest rates. An installation of small tools, sewing machines, for example, which, although used intermittently, average the load demand to a practically constant figure, is another class of work where low rates are given, but for ordinary machine work it is practically impossible for power users to obtain current at a flat rate of one penny per unit. Very frequently a compound rate is charged. A certain number of units consumed (a certain proportion of the total load) being rated at, say 1½d., while the amount of current consumed beyond this would be charged at, say ¾d. In ordinary work it is almost impossible to use as much current as would bring the total charge down to a flat rate of 1d. per unit, as usually it is somewhat in the neighbourhood of a 1⅛d. or 1¼d. per unit. Upon this basis it would cost about 1d. for every b.h.p. per hour seeing that losses due to the friction or efficiency of the motor itself when running at its proper speed means that between 0·87 and 0·9 of a unit is required for each b.h.p. given off by the motor. A factory then whose normal load would be about 30 h.p. throughout a day of ten hours (that is to say, while perhaps 10 h.p. would be developed at some periods, 50 h.p. may be taken at another time, and that between these two extremes the average would be 30 h.p.), the cost of a day's work under such conditions would be 300d. or 25s. On the other hand a Gas engine fed with gas at 3s. a thousand feet and consuming 17 cubic feet of gas per b.h.p. per hour, when dealing with a load averaging 30 h.p. for ten hours, would require 5,108 cubic feet of gas for the day's work, costing 15s. 4d. This saving of nearly 10s. per day amounts to a considerable sum for a year's work—for 300 working days the total saving would be £150.

It may be said, however, that the total cost of the work done by a Gas engine is not 15s. but a higher amount which should include the cost of lubricating oil, and a portion of man's time cleaning and attending to it. It may also be said that a Gas engine takes up more space than an electric motor, and that it is more liable to give trouble through vibration while it also requires a supply of water for cooling the cylinder jacket. Granted that all these additions should be made, and are assessed at a cash value, a Gas engine can still claim a substantial saving, while its mechanism is such that it is easily understood by an intelligent man and it has much less risk of breakdown.

It is well known that the experience of insurance companies has proved that the highest proportion of breakdowns in prime movers occur to electrical machinery. Indeed, the British Engine Boiler and Electrical Insurance Co., Ltd., have stated that one in every eight of the selected motors insured by them have broken down, while, taking electrical machinery as a whole, the proportion is one breakdown to every three electrical installations.

It is to be hoped that this state of things will be improved as time goes on, but electrical machinery is usually underrated as regards capacity for continuous work, while it is liable to be stopped without warning at any moment through accidents outside the factory. In the comparison given of the cost of running no mention has been made as to the cost when Suction producer gas is used instead of the gas supplied by the public companies. When this is taken into account electric motors cannot compete.

These comparisons may be summed up by saying that there is no doubt that electric driving offers very many advantages, but in most cases it will be found cheaper for the power user to instal his own generating plant if he has room for it and has to keep an attendant for other work, rather than take a service from the public mains unless his load is such as will give the supply company what is called a high load factor, and thus a very low rate per unit be secured.

CHAPTER II.

GAS ENGINES VERSUS OIL ENGINES.

Where gas is procurable from public supply mains at a price not exceeding 4s. per 1,000 cubic feet it is generally found more economical and more convenient to instal one of these Engines in preference to an Oil Engine.

Compared with Gas Engines served by producer gas the ordinary types of Oil Engines cost more to run. But Oil Engines for powers up to 20 H.P. have some advantages which may turn the decision in their favour.

Considerations of relative fuel cost; the amount of water necessary; the simplicity of apparatus; the short period necessary for starting up; the ability to deal with varying grades of oil; and the slight attention necessary during work, are some of the points which favour an Oil Engine as compared with a Gas Engine and Producer Plant. Especially in country districts remote from a railway goods station, both in England and abroad, are these advantages emphasised. In all installations subject to sudden and extreme variations of load, the Oil Engine responds to the power demand immediately, while the Gas Engine and "Suction" producer responds less readily.

The Diesel Oil Engine is of a distinct type, and, above all other Oil Engines, compares favourably with even high power installations.

The circumstances of each individual installation vary so much that the relative advantages cannot be summed up in a few words. Undoubtedly, while the demand for Oil Engines is increasing year by year, the advent of the "Suction" Gas-producer consuming anthracite or coke has influenced many in the direction of installing gas power with satisfactory results.

A fair comparison of the working costs and capital expenditure may be made as follows :—

A. Gas engine 20 B.H.P., with "Suction" Gas-producer, running on ¾-load with no special attention to obtain most economical results. Running for 5 days per week, 4 hours each day, 52 weeks per annum for 5 years. Average B.H.P. developed 15. Fuel consumption at the rate of 1⅛-lbs. of anthracite per B.H.P. hour. Average cost of anthracite taken as 25/- per ton throughout the five years.

	£	s.	d.
Capital outlay on engine and plant	£240	0	0
Carriage, fixing and foundations	35	0	0
Repairs and renewals	35	0	0
40 tons of anthracite @ 25/- per ton	50	0	0
Extra attendance over oil engine	13	0	0
Interest (5%) on £275 for 5 years	68	15	0
	441	15	0
Less value of plant at end of 5 years ...	120	0	0
	£321	15	0

B. Oil engine 20 B.H.P. running on ¾-load with no special attention to obtain most economical results. Running 5 days per week, 4 hours each day, 52 weeks per annum for 5 years. Average B.H.P. developed 15. Fuel consumption at the rate of ¾-pint of oil per B.H.P. hour. Average cost of oil taken as 4d. per gallon throughout the five years.

Capital outlay on engine	£170	0	0
Carriage, fixing and foundations	30	0	0
Repairs and renewals	25	0	0
Cost of oil at 4d. per gallon	121	17	6
Interest (5%)on £200 for 5 years	50	0	0
	396	17	6
Less value of engine at end of 5 years ...	85	0	0
	£311	17	6

Upon such basis it will be seen that there is little to choose between a Gas Engine or an Oil Engine of this size and under such conditions. Taking into account the cost for water to the producer, the quickness in starting, and general simplicity of the Oil Engine, the claims of the latter are deserving of careful consideration. Naturally, larger engines more fully loaded and more continuously worked would show greater differences, and these would in the majority of cases point to the Gas Engine as being the more economical power. But for small engines and those of moderate power where the work is intermittent Oil Engines are convenient and probably of greater service.

CHAPTER III

GAS ENGINES VERSUS STEAM ENGINES.

Of late years there have been many discussions as to the comparative merits of Gas and Steam Engines. Each power has its own particular advantages, and general statements based on individual applications under widely different circumstances cannot be held to decide the best type of prime mover for all purposes.

The great strides made during the last few years have proved that there is no difficulty in building and running Gas Engines of as large units as is possible in Steam Engines, and for the factory owner, therefore, there is no limit of size at which gas power has to yield place to its older rival.

There is no doubt that the majority of factory proprietors who have had occasion to instal new power during the last five years have decided for gas power, and, with equal certainty, this decision has been found to be perfectly satisfactory in practical work in the majority of cases.

That some Gas Engines have given cause of complaint is indisputable, but these cases have been rare, and the troubles have been due in most instances to the incompetency of the purchaser in buying plant too small for the work, to the incompetency of the erector in fitting up the installation, or to the incompetency or mis-directed zeal of the attendant.

A Gas Engine of proper size, properly fixed and properly attended to, as are the majority in use to-day, give every satisfaction, and perform their duties with utmost regularity and reliability. Many are at work night and day from Monday morning till Saturday night, thus proving that comparison with Steam Engines must be made upon other grounds, as here, at all events, equally good results are obtained from each.

Experience with Gas Engines in practical work has also shown that, above all other advantages, it is possible to get more work out of a pound of coal with a Gas Engine and producer than can be obtained with Steam Engines, unless the latter are of high power, using superheated steam, with condensers, efficient boilers, feed water-heaters, water-softeners, and similar auxiliaries (which, although they levy a toll in working, still allow more heat to be recovered than they absorb in operation). For the highest powers under circumstances that permit their use, high speed Steam Turbines give equally good results as

Gas Engines do, while the total cost of a turbine set, including capital outlay, show an advantage when compared with a gas power plant consisting of engines, producers, ammonia recovery plant, purifiers, etc.

With these large installations, however, the present handbook has little to do, as it is written for those whose total power load is 100 H.P. rather than 1,000 H.P. For such moderate powers Gas Engines show to best advantage, as the gas-producer can be of the simplest type, while the whole equipment may be run with a minimum amount of attention by one man, giving him ample opportunities for such other work of but secondary importance as may occupy his spare time.

For factories that require power and lighting a gas power installation has many advantages. The absence of boilers (with the incessant stoking, with the smoke nuisance, with the gradual lessening efficiencies due to scale, with the risk of explosion through one of many causes, with the risk of burst steam pipes, etc.), brings a general sense of relief and freedom from anxiety on account of the possibilities that may follow from the slightest neglect on the part of the engineer-in-charge. The supercession of the stoker also means that a frequent source of waste has been entirely removed, as a thoughtless or untrained man can easily cause the coal bill to be increased 15 or 20 per cent.

With regard to the actual lessening of fuel costs by means of Gas Engines in practical work, the following particulars are interesting, emanating as they do from the factory owners themselves.

Previous Cost of Working.			Cost with new Gas Power Installation.	
Place.	Type.	Running Cost per week.	Type.	Running Cost per week.
Beckenham	12 H.P. steam engine and boiler ...	80/-	24 B.H.P. gas engine ...	36/- with town gas.
Huntly, N.B.	6 B.H.P. steam engine and boiler ...	36/-	16 B.H.P. gas engine and gas producer	6/-
Dundonald	10 H.P. steam engine and boiler ...	35/-	Gas engine and gas producer	4/-
Barnard Castle	Three steam engines of 12, 10 & 5 N.H.P.	20/- to 40/-	25 B.H.P. gas engine ...	9/6
Glasgow ...	Steam engine and boiler ...	42/-	Gas engine and producer ...	22/- with town gas & 8/- with suction gas.

A well-known firm of Reading had a large Steam Engine made by one of the most celebrated Continental engine-makers, and two smaller Steam Engines. Their coal consumption per H.P. per annum under these conditions was, in 1899, 7,923 tons; in 1900, 10,021 tons; in 1901, 10,562 tons. During 1902 the producer plant and Gas Engine were installed, so that the figures cannot well be separated. In 1903, when all the machinery was driven by the Gas Engine, the consumption per H.P. per annum was 2,925 tons; in 1904, 2,016 tons; and in 1905, 1,877 tons.

During the last-mentioned year there were, in addition to the 250 B.H.P. Westinghouse Engine, five other Gas Engines.

By the use of the modern plant the fuel consumption per H.P. per annum has been cut down to almost one-sixth.

A comparison between the years 1899 and 1905 is instructive; the average load in the latter year was exactly double what it was in the former; the total fuel consumption for the year is considerably less than half in 1905 what it was in 1899.

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CHAPTER IV.

THE COST FOR GAS.—"TOWN" GAS.

The cost for gas varies, of course, with the price of the gas available; it also varies with its quality, temperature, and pressure, as well as with the amount of power given off by the engine in relation to its maximum power.

When gas can be obtained at 2s. 6d. per 1,000 cubic feet, the cost per Brake horse-power per hour is about ⅝d. (this being reduced to ½d. in the larger sizes), when the engine is working under *full* load. Under *half* load the cost would approximate to ¾d. per Brake horse-power for the smaller sizes and to ⅝d. in the larger.

The quality of the gas varies with each gas company, and, in order to provide a standard for comparison, gas of 700 British Thermal Units heat value (not higher but lower heat value) is usually taken as a basis for calculation.

It will be noticed in the preceding paragraph that two heat values—" higher " and " lower "—are given to the same quality of gas. The lower or net heat value only is of use in a Gas Engine—the gross or higher value including heat which cannot be converted into work.

In Manchester this standard quality is practically obtained, but other towns in the United Kingdom are generally not so well favoured.

The consumption of gas of standard quality, per Brake horse-power per hour, for engines of various sizes is given below, when under full and half loads :—

Size of Engine.	Consumption per B.H.P. per hour.	
	Full Load.	Half Load.
Up to 12 B.H.P.	20 to 17 cub. ft.	25 to 20 cub. ft.
12 to 20 ,,	17 to 16 ,,	20 to 19 ,,
20 to 60 ,,	16 to 14¾ ,,	19 to 18¼ ,,

In calculating probable cost for gas, it will of course be necessary to correct the above figures according to the quality of the gas available, and in order to do this the local gas company should be asked for a statement as to the heat value of their gas in terms of British thermal units per cubic foot, and to notify whether it is the higher or lower value. It must also be borne in mind that the actual cost for gas will probably be much less than the above figures indicate, owing to the fact that the governing devices fitted to the engines automatically control the gas supply, and, by causing the gas charge to be omitted when the speed is above the normal, effect a very considerable saving.

An appreciable amount of gas is, of course, consumed in keeping the engine with its own contrivances in rotation at the proper speed. The cost for gas when the engine is running without load is of great importance, as, being a constant " frictional " consumption—irrespective of the quantity of gas needed for the engine's load—it represents a standing charge. Therefore an engine, of few working parts, requiring a minimum quantity of gas to overcome its own friction, is to be preferred.

The necessary particulars required to properly compare the engines of various makers upon a uniform basis—as regards consumption of gas, etc.—are embodied in the suggested form of enquiry printed on page 62.

CHAPTER V.

THE COST FOR GAS.—PRODUCER GAS.

When Gas Engines of moderate power have to be driven, and space can be spared, it is usually more economical to instal a " poor-gas " producing plant than to purchase towns' gas, as the cost of the latter for Gas Engines of the larger sizes renders it disadvantageous for use unless power is required intermittently.

Producer, or poor gas, is made by passing steam (sometimes superheated) and air through a " generator " containing incandescent anthracite coal or washed gas coke. As the steam and air pass through they mix with the products given off by the burning fuel, and issue from the generator as " producer gas." By causing this low quality gas to pass through a " cooler," a " dustbox," and a " scrubber," it is cooled and cleansed before passing to a reservoir from which the supply pipe to the engine is taken.

Producer gas, being of much poorer heating value than towns' gas, is not able to give off as much power from an equal volume. A Gas Engine designed to give off a certain amount of power with ordinary towns' gas, will only give off about 80 to 90 per cent. of that power with producer gas, and the quantity of the latter consumed will be about four times as much as the quantity of towns' gas.

The cost of "Dowson" or similar producer gas from a "pressure" plant varies with the price of the fuel obtainable, but as a rough figure, 2d. or 3d. per 1,000 cubic feet may be taken as a fair basis for calculation. It must be borne in mind, however, that these figures really represent 8d. or 12d. per 1,000 cubic feet, having regard to the fact that about four times the quantity of producer gas is wanted to develop within 10 or 20 per cent. of the power of towns' gas, as explained above. The saving effected by using producer gas for a large engine, or for 2 or 3 of moderate power, is very considerable, and where space can be spared and proper attention given, the results soon justify the cost of the installation.

Blast furnace gases are also utilised for supplying Gas Engines, with satisfactory results.

Gas making plants may also be purchased which convert waste oils and fats into a poor gas suitable for driving Gas Engines.

"Mond" producer gas will probably in many instances supersede the producer gas made from anthracite or gas coke. Dr. Mond, working the furnace at a lower temperature, uses a bituminous coal, and while producing a gas about ⅓rd more powerful than blast furnace gas, recovers from the fuel about 90 lbs. of sulphate of ammonia per ton, thus obtaining a very valuable bye-product, and thereby greatly reducing the cost of gas. The " Mond " plants, however, are not made smaller than of a size equal to supplying gas sufficient for loads of about 250 Indicated horse-power.

Gas-producing plants are being greatly developed, and are offered for engines of ten horse power upwards. " Suction " plants, which do not require a reservoir or gas-holder, and plants that make satisfactory gas from ordinary bituminous coal instead of the more expensive anthracite, are now in successful daily work. At the end of this book a chapter is added upon " Suction " plants, as such producers are likely to be widely adopted by users of Gas Engines from 10 Brake Horse Power upwards.

CHAPTER VI.

COST OF "UP-KEEP" OF A GAS ENGINE.

The cost of keeping a Gas Engine in good working order varies with the amount of attention bestowed upon it. The parts requiring more frequent renewals are the ignition tubes, piston rings, and, on the larger sizes, timing valves. The parts that require the more frequent attention and adjustment are the air and exhaust valves and the bearings, especially the brasses at each end of the rod connecting the piston with the crank.

Usually it is found sufficient to thoroughly clean the engine and make the necessary adjustments occasioned by wear and tear, once every three months. The expense incurred varies with the size of engine. For the smaller sizes a couple of men's services for half a day is usually sufficient, but if the bearings want much attention a whole day is sometimes necessary. In any case 20s. would probably cover the men's time and material used and allow for overtime (except night and Sunday work). Five pounds per annum would be a fair sum to allow if no heavy repairs be necessary. Larger engines cost more in proportion, the parts being heavier, larger, and not so easily handled.

At the end of 4 or 5 years the cylinder liner will probably require re-boring, and a new piston of slightly increased size will have to be purchased from the maker. For engines up to 15 or 20 B.H.P. probably a £5 note would cover this expense.

Later on the liner will again show signs of wear, and probably will not stand re-boring a second time. A new liner entirely will therefore be required, as well as a new piston to suit it. The cost of these, for engines up to 15 or 20 B.H.P., would probably be £10 to £12, if the same cylinder casing be used. The cost can sometimes be reduced and precious time saved if the makers happen to have a cylinder casing of similar size at their works, as, in such a case, it is possible for the new liner and its casing to be already fitted together when delivered on the site. The old liner in its casing is then removed and the new one put in its place at the expense of but little time and trouble. The old liner and its casing would in that event become the property of the makers, and be returned to them to be kept until some other engine requires similar repairs, when the secondhand casing—which, not being subject to wear, is practically free from deterioration—is fitted with a new liner and despatched for use on another engine. Failing this method, a new liner as now supplied by most makers, can be easily fitted "on the site," but more time will be taken up—a thing to be avoided when stoppage of work means loss of money.

The life of a Gas Engine may be taken as about 15 to 20 years, more or less, according to the work put upon it during its period of service and to the attention and care bestowed.

CHAPTER VII.

THE COST OF ATTENDANCE.

Regarding only the daily attendance necessary for oiling, starting and stopping, and excluding all renewals and repairs, which have been dealt with under the item of " up-keep," the cost of keeping a Gas Engine is but a nominal sum. Most modern engines are fitted with porcelain ignition tubes, and five or ten minutes only is necessary to light the bunsen furnace round the tube, oil up all bearings, and start the engine. At meal times the gas supply to the bunsen furnace as well as to the engine is shut off, and the only care necessary is to see that the engine is left at rest with the crank on the bottom compression centre; this ensures that all valves in the engine are closed. The bunsen furnace can, of course, be left alight if found more convenient, so that a start can be made at any moment.

At the close of a day's run the engine should be cleaned up with cotton waste and left with all valves closed.

Unless the pressure of gas is very variable throughout the day, rendering frequent adjustment of the gas valve necessary, 30 or 40 minutes is the average amount of time the engine would encroach upon a man's day's work. The cost of attendance would be therefore 4d. or 5d. per day.

CHAPTER VIII.

THE COST FOR WATER FOR A GAS ENGINE.

Unless the engine is worked for long hours, or has an insufficient amount of water in circulation, the supply of water necessary for a Gas Engine is a negligible quantity after the tanks have been once filled, evaporation only requiring perhaps a bucketful of water a week to be added to the original quantity.

If the tanks are too small, or not sufficiently exposed to the outside temperature to allow of proper cooling, it is necessary to add another tank, or to run in cold water, towards the end of a day's run, sufficient to keep the engine cylinder at such a temperature that the hand can be placed on the top of it without discomfort.

If the exhaust gases are cooled by means of a small jet of water, to obtain silent exhaust to atmosphere, the water bill will of course be increased, but a small quantity only is necessary to do what is wanted, and probably only slight increase need be allowed for if the engine is of moderate size.

CHAPTER IX.

THE COST OF ERECTION.

It is difficult to state a sum which would cover the cost of erection of a Gas Engine, as it varies greatly on account of the lengths of piping required, amount of cartage necessary, and the difficulty, if any, encountered in preparing the foundation and placing the engine upon it. The average cost of engineers' work, erecting engine on foundation provided, connecting up with fairly short pipes, and adjusting all to proper working order, usually amounts to about £1 per B.H.P.—rather under for the larger sizes, and rather over for the smaller sizes—if the site is within 20 miles or so from the engineers' depôt. The minimum cost for erection (engineers' work) in the small sizes is about £5 to £6.

The extra cost of foundation and builders and carpenters' work varies so much that no figures can well be given. Perhaps, as a rough guide, an allowance of half as much as the cost of engineers' work would cover expenditure necessary under this head.

The above figures for engineers' work include unskilled as well as skilled labour, and, in this connection, it may be well to state that a labourer who is used to working under his mate saves a great deal more time than one not accustomed to the work. It is often stipulated in specifications that the unskilled labour shall be provided by the power user, but the cost is then rather increased than reduced because of the incompetent help that the skilled man has to depend upon. It is usually wise to let the erector have the assistance of at least one man, who can prepare, on his own initiative, for the next detail which will require the skilled attention of the mechanic.

CHAPTER X.

THE POWERS OF GAS ENGINES.

Unfortunately for purchasers of Gas Engines, Gas Engine builders do not adopt a standard rating to describe the output of their engines.

The total effort of the exploding gases upon the piston is, of course, the maximum power developed; and, as this is usually measured by means of an instrument called an Indicator, the term INDICATED HORSE-POWER is used to denote the total power exerted upon the piston, whether the power is obtained by steam, gas, oil, hot air, or fluid pressure.

A certain proportion of the total power exerted upon the piston (or Indicated H.P.) is absorbed by the friction of the moving parts of the engine, therefore the term Indicated H.P. is not in itself a reliable guide as to the power that the engine is capable of giving off to another machine, seeing that some engines have more moving parts than others, and therefore more internal friction. The amount of power available for driving other machines is termed BRAKE (or EFFECTIVE or ACTUAL) HORSE-POWER, because the contrivance by which this power is measured includes a band, which acts as a brake to the motion of the fly-wheel.

The two terms "Indicated H.P." and "Brake H.P." are sufficient to denote the power of an engine worked by steam, the output of which can be kept up hour after hour so long as the steam pressure available is constant. In Gas Engines, however, the term Brake H.P. has to be further qualified, as, owing to the heat generated by successive explosions being imparted to the cylinder, the latter cannot be kept cold enough to extract all heat and power from the exploding gases during the "power stroke." The usual allowances advised by Gas Engine makers to cover the difference between the output of the engine under brake test and the OUTPUT UNDER CONSTANT WORK are about 12½ per cent. when variable loads are carried; 5 per cent. under intermittent work (sawing for short periods, etc.); and 20 to 25 per cent. for sustained heavy loads such as pumping or electric driving.

Briefly stated the various terms of horse-power as used in connection with Gas Engines are as follows :—

Indicated H.P.	is the total amount of power developed by the explosions.
Brake H.P.	is the maximum amount of power available for driving other machines.
Test Brake H.P.	is the maximum amount of power given off from the engine flywheel under the most favourable conditions and expert attendance.
Working Brake H.P.	is the amount of power that can fairly be reckoned upon as a maximum output under ordinary working conditions, and this varies with the class of work as explained on the previous page.
Nominal H.P.	is a term deservedly going out of use. It was formerly used to denote the size rather than output of *Steam* Engines, and was from $\frac{1}{3}$rd to $\frac{1}{2}$ of the maximum power for which the engine was suitable. Having no definite value, the term was no indication whatever as to

the actual power to be expected from Gas Engines, and had to be dropped, as some makers who left a fair margin of reserve power found that others were rating their engines almost up to the maximum power, thus taking advantage of those purchasers who were ignorant of this.

When deciding the size of an engine the power required by each machine to be driven should be carefully reckoned, and to the total of those powers an ample allowance should be made for friction of shafting and belts, and a still further margin provided for future extensions, as well as for loss of power owing to occasional bad quality or bad pressure of gas, and leakages past piston and valves, etc., due to wear and tear.

When erecting new machinery the makers should be asked to state what actual or Brake horse-power their machines require at the driving pulley. The answer should state a definite amount, and not an indefinite " nominal " term.

In existing factories the engine in use can, in most cases, be " indicated," and a competent engineer will be able to advise as to the Indicated horse-power required under varying conditions of work. Diagrams should always be taken when only the engine, shafting, and belts are in motion. This source of friction is very often understated, the consequence being an almost complete absorption of any margin that had been estimated for other purposes. As a matter of fact, most factories, especially those that have been at work for a good many years, would greatly economise in working expenses if the shafting and bearings were overhauled, even only once a year, and necessary alignments and adjustments effected.

When selecting an engine bear in mind that one of a larger size than actually needed practically costs no more to run than one of smaller power. Only the slightly increased frictional resistance of the larger surfaces, etc., act upon the consumption of gas. When dealing with light loads the governor will permit only a sufficient number of explosions to maintain the normal speed of rotation. The advantage of being able to increase the work above the usual load compensates for any very slight increase in frictional losses when within reasonable limits.

CHAPTER XI.

NOTES ON DESIGN.

In comparing the engines built by different makers, it is sometimes necessary to descend to details before a final decision is possible, as power, efficiency, and economy being equal, and the price practically so, it is then that subsidiary questions assume importance. These notes are intended to call the attention of intending purchasers to various points of difference.

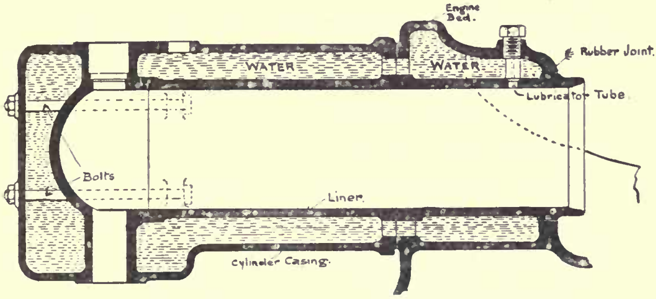
DETACHED CYLINDERS.

Most Gas Engines are now built with the cylinder an entirely separate casting, fastened to the bed by strong bolts or studs, either against a vertical or horizontal face. Others, however, are cast with the bed and cylinder in one piece. The makers of the former type consider that a separate casting is preferable, as, in case of accident (such as bursting by frost, if the water has been allowed to remain round the liner in winter weather), renewals can be easily effected. In renewing the cylinder liner, for example, when the cylinder casing is a separate piece and made to gauge (as is now universal) the new liner can be fitted to a second-hand casing and be at hand ready to be put in the place of the old one without any delay, and (as in most modern engines) without any troublesome combined gas and water joints to make, which a " bed and cylinder combined " casting necessitates.

Some Gas Engines with separate cylinders, however, are designed that water is circulated round that portion of the liner that projects into the bed casting, making a water joint necessary. Other makers, however, provide ample air space only, and allow no water to enter into the main engine casting, so as to do away with a troublesome joint and the risk of fracture by frost of the main casting.

Engines built with cylinder and bed in one piece are not open to the criticism of overhanging cylinders (to the same extent as the separate castings), no studs being necessary for securing the cylinder to the bed. A separate combustion end is fitted, however, which involves a water joint, and as all gas, air, water, and exhaust connections have to be arranged upon this portion, it is not always so get-at-able, as far as adjustments are concerned, as is the separate casting type.

Gas Engines in both designs have been built up to large powers with equally satisfactory results, so that the difficulties of either type seem to be more matters for argument than for serious consideration.



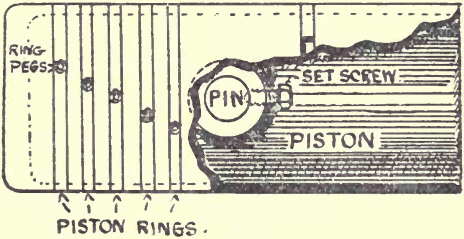
SEPARATE OR "LOOSE" LINERS.

The advantages of a separate liner are so great, especially in the horizontal types of engines, that their application is almost universal. Being cast separately from the bed the foundry work is much simplified, and the metal can be made of specially hard material, more suitable for withstanding the wear occasioned by the constant movement of the piston and its rings. It can, moreover, be easily re-bored or replaced, even by local engineers. It is often possible for the makers to send a new liner and piston, when they are necessary, already fitted to an outer casing taken from an engine of similar size. The consequent stoppage is therefore considerably curtailed, as the new one can be on the ground before the old one is removed.

The liners are secured to their casings by means of bolts passing through lugs on the liner and holes in the jacket or casing. Some makers secure them by bolts to the closed end of the cylinders, through the water space at the combustion end of the cylinder casing. These bolts have to be of fair length, and are therefore subject to extension when in work and contraction when cold. To obviate these long bolts other makers secure their liners to the open or crank end of the casing; short bolts can then be used, and the alternations of heat and cold are not so much to be feared; but this method demands that the cylinder shall be removed whenever it is necessary to tighten these short bolts.

PISTON AND RINGS.

The piston is made of specially hard metal, to resist wear, and fitted with soft cast-iron spring rings, to obtain a good working fit with the minimum of expense for renewals. The rings, being of softer metal than both liner and piston, wear the more readily, and are cheaply and easily renewed. The piston itself should be of ample length, so as to provide a large area of bearing surface and to be less liable to " kick " at the extreme positions, " in " and " out," under full working load. The most usual method of fitting the rings is to turn five or six grooves in the outer diameter of the piston, and in each groove to fit a peg in such a position that no two pegs are in direct line with each other parallel to its length, but are placed spirally round its circumference. The cast iron rings have their split ends filed to suit these pegs, and are sprung to their places over the maximum diameter of the piston. Care has to be exercised in this operation, as there is very little " spring " in cast iron, and fractures are of frequent occurrence. Piston ring pliers can be obtained from most " engineers' stores," which greatly minimise the risk of breakages.



Some makers make their pistons with a detachable end, or " Junk " ring, which allows the spring rings to be of more accurate size, to be put in their proper places without being strained, and also to be more easily removed for cleaning. The detachable end, however, has to be secured by screws, and these, if not carefully replaced, are likely to become loosened during work, with the possibility of damage.

The proper lubrication of the piston is a most important matter in a Gas Engine, owing to the high temperatures and flame the oil is brought into contact with. Many engines have been ruined by the use of improper oils, which, not being able to live in high temperatures, burn and form a gummy deposit on the piston, causing great loss of efficiency and entire failure of lubrication. The good quality of oil necessary for this special work is emphasised by the Gas Engine makers, who make it a condition of their guarantee that, during the period covered by the same, their special brand of oil only shall be used for lubricating the piston of the engine. Lubrication for the piston is given at a uniform rate (so many drops per minute) by means of mechanical movement, either by a positive toothed wheel-and-ratchet movement, or by a small belt driven from the cam shaft.

CRANK SHAFTS.

Some Gas Engine makers prefer to form the crank shafts for the smaller sizes of their engines from a straight bar of round steel by pressing it to shape in suitable hydraulic machines. It is claimed that the " grain " or " flow " of the metal is in this way retained, and is not so disturbed as when the "throw" or "crank" is slotted out from a solid forging. This bent shape, however, can only be used in the smaller sizes, as, with increased diameter, the curves have to be at greater radius to avoid injury to the metal, and beside the inconvenience and difficulty of handling and shaping such large crank shafts, the engine frame would of necessity have to be widened. Forged cranks, with throws slotted or cut out, are, therefore, more suitable for the larger engines, as the cranks can be made with cheeks much closer together, and thus the main bearings can be placed closer to the crank pin, thereby adding to the stiffness of the engine and greatly improving its appearance.

Several makers fit all sizes of their engines with cut cranks, on account of their smart appearance, and claim that the machining to which it is subject is more likely to reveal hidden flaws or defects, and that it is, for this reason, a safer crank.

Both types of crank are largely used, and, when properly designed to give sufficient strength where necessary to withstand the strains, give equally good results.

NOTES ON FLYWHEELS.

It is often a puzzling thing to a purchaser to be told by some Gas Engine firms that two flywheels are necessary for efficient working, while other makers supply and fit only one, and obtain equally good results.

The makers who fit two flywheels claim that the strains upon the engine crank shaft and wear upon the crank shaft bearings are then equalised to a great extent. Makers who fit one only on the smaller sizes say that the provision of the necessary weight in one wheel of large diameter not only allows better governing than two wheels of the same total weight of smaller diameter, but, by supporting the weight of the one flywheel at the part of the shaft most suitable to bear it (viz., close to the bearing on the side of the engine opposite the cam shaft), and taking the power by belt from the pulley on the cam shaft side, placed as close as possible to the gear wheel box, the strains on the crank and bearings are sufficiently equalised. On the two flywheel engines one of the wheels is supported close to the bearing on one side, but the second wheel is several inches from the bearing on the other, the gear wheels intervening; the driving pulley is placed outside either of the flywheels, and is, therefore, not so well supported as on the single wheel engines. One firm of Gas Engine builders, to get over this difficulty, place the gear wheels between one side of the crank and its bearing; thus the flywheels can both be well supported. But this method gives rise to some criticism, as the crank, by means of which all the power from explosions is transmitted, is not then supported by bearings equally distant on either side.

On all Gas Engines above 20 Brake H.P. the weight necessary for efficient working is of such amount that it is found better to cast two wheels instead of one, for convenience in handling and transit. Smaller sizes also are fitted with two wheels when a more than ordinary uniform speed is wanted, as in dynamo driving, and when the work is likely to subject the engine to sudden demands for full power, as in saw mills with circular sawing machines. For electric lighting, where the engine drives the dynamo direct for incandescent lamps, two flywheels do not give such good results as one of extra heavy weight; and the majority of makers offer such an engine, with a wheel on a suitably strengthened crank shaft, supported by a third bearing.

Some persons seem to be under the impression that an engine fitted with two flywheels gives off more power than an engine of similar size fitted with one only, but this is contrary to fact. Even if the two flywheels were each of equal weight to the single wheel, the only advantage would be, as above stated, more uniform speed under suddenly varying loads. This greater uniformity, however, would be obtained at the cost of increased engine friction, as to keep two wheels revolving at high speed requires more power than to keep one.

Gas Engines fitted with one flywheel permit a variation in speed of from 5 per cent. to 7 per cent. when the full load is suddenly thrown off. When two flywheels (doubling the weight of one wheel) are fitted, the variation is from 4 per cent. to 5 per cent. Engines fitted with one single extra heavy flywheel, as used for electric lighting, restrict the variation under similar circumstances from 2 per cent. to 2½ per cent.

Notes on Governing.

The most usual method adopted for governing the speed of Gas Engines is to provide automatic means whereby the gas charge is omitted when the normal speed is exceeded. The designs of the governors vary considerably, but the majority are of the "hit and miss" principle. A very simple and efficient form is adopted by a well-known firm in the smaller sizes of their Gas Engines up to 23 Brake H.P. A comparatively heavy block of metal, of special shape, is given an upward movement, as on an incline, by means of the forward movement of a cam, and thus is made to actuate the admission cock when the speed is "normal." When, however, the speed of the cam is above the normal, the impetus given to the block causes it to rise to a greater height, and the "pecker" inserted in the block shoots over, and thus misses, the projecting portion of the gas valve spindle, thereby causing the engine to inhale air only, instead of the explosive mixture. A spring, the tension of which can be adjusted by a screw and lock-nuts, is used to effect changes of speed, and can be operated while the engine is at work.

A common type of governor on the "hit and miss" princple makes use of a movable weight upon a small rod, the momentum of which at varying speeds similarly engages or misses the gas valve spindle. A governor of this design, however, cannot usually be adjusted to give more or less speed to the engine while the engine is in motion, and the movable weight is liable to shift its position if not fastened securely in its proper place.

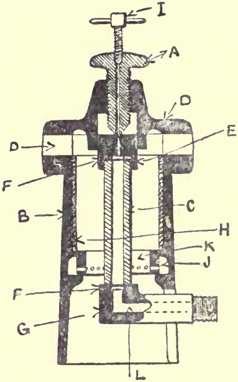
For all engines of larger sizes a centrifugal pattern governor is generally adopted by the makers; but some prefer to fit the centrifugal type throughout all sizes, as is the universal practice in steam engines. The balls are made to rotate by means of gear wheels from the side shaft, and at the designed speed they lift a weight on the central spindle, and thus actuate one end of a lever, at the other extremity of which a piece of metal is hung. This piece of metal is of sufficient length to make a connection between the gas valve spindle and another block of metal pushed forward by the governor cam, and the governing is effected by the gap piece being lifted (or sometimes depressed) out of the way when the normal speed is exceeded, and so the connection between gas valve spindle and governor cam is broken. Some makers use the centrifugal type of governor to actuate a lever in a similar manner, but, instead of a suspended gap piece, the lever moves a loose sleeve along a spindle connected with the gas valve lever, and when the speed is excessive the sleeve is moved out of the way of the cam, which would otherwise engage a projecting ring of the sleeve and cause the gas valve to open. A spring with lock-nuts is usually fitted in connection with the governor lever, and, by being altered in tension, more or less hinders the movement of the sleeve or gap piece, thus providing means to vary the speed when desired. In starting engines fitted with governors of this type it is necessary to prop the governor lever in such a position that the gap piece, or loose sleeve, is held in line with the gas cam until the ordinary speed is attained, when the " prop " or " sprag " should automatically fall out of the way.

NOTES ON IGNITION.

The usual method of firing the explosive mixture is by means of a heated tube, placed in connection with the cylinder either by direct communication or through a mechanically moved timing valve, which, at the proper instant, allows the compressed charge to enter the tube; the explosion thereby is timed to occur only when the piston has arrived at its proper position to receive the full effect, namely, at the commencement of its " out " stroke.

The tubes are sometimes of iron, but the life of these is of but a few hours' duration. Other engines are fitted with tubes of special alloy, which last a few months. The most modern engines, however, have a clay or porcelain tube of about 4 inches in length, which, while lasting a much longer period, cost very few pence to replace.

Some makers claim that a certain position at the *side* of the engine cylinder gives the best results, but the position of the valves in relation to the shape of the combustion chamber may decide that the more effective position for another make of engine would be at the cylinder *end.* No hard and fast rule can therefore decide this point, and statements such as that just mentioned should be accepted with reserve.

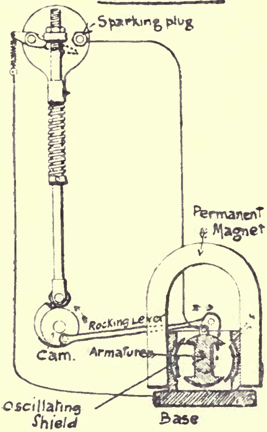


A	Tightening Screw
B	Cast Iron Guard.
C	Clay Tube.
D	Top of Guard.
E	Top Cap.
FF	Asbestos Washers.
G	Tube Holder.
H	Asbestos Lining.
I	Relief Screw.
J	Gas Passage.
K	Flame Ring.
L	Passage to Cylinder.

As above stated, the tubes in the most modern engines are made of clay or porcelain, and are about four inches long. They are clamped to the cylinder between an angle piece of metal—with a central hole connected with the interior of the engine—and a top cap and tightening screw. This screw passes through the top portion of the iron guard surrounding the tube, which in turn is fastened to the bottom portion of the guard by a bayonet joint. The tightening screw allows adjustment to be made to take up any slackness occasioned by the continued alternations of heating and cooling of the tube. A small hole is sometimes drilled in the top cap and tightening screw, so that, in conjunction with an auxiliary screw, an escape of some of the contents of the tube can be provided at will, the object being to facilitate starting the engine by providing a slight relief. When the engine is in motion, however, this relief must be shut before the load is put on.

The tubes are surrounded by a cast-iron guard, made in two portions. The lower portion forms a connection with the bunsen burner, and conducts the flame, through small holes drilled circumferentially, round the ignition tube. Inside the lower portion of the guard, or chimney, a ring of asbestos is placed to concentrate the heat at one portion of the tube, and by this means a very effective furnace is obtained, capable of keeping the tube at a bright red heat. The bunsen burner is adjustable as regards admission of gas, and the whole fitting can in some cases be raised or lowered as necessary to retard or accelerate the instant of firing, while in larger sizes a separate and adjustable valve is provided to "time" the moment of ignition with absolute certainty.

Ignition by electric spark is adopted, but in England, as a general rule, only in those cases where towns' gas cannot be obtained for heating an ignition tube. Either of two methods is employed, one by means of an electric battery and induction coil, and the other by a magneto electric machine, in form very similar to an electric dynamo. The latter is preferable to batteries and less expensive to keep in working order, and the magnets, when weakened by constant use, can be readily re-magnetised.


Magneto Electric Machine and Sparking arrangements

Electric Ignition is always to be preferred for Gas Engines served with Producer gas. A variable timing device can be arranged by means of which the instant of explosion can be adjusted to suit the varying qualities of gas given off from the generator—especially when starting. This adjustment is a great advantage over fixed timing which cannot be altered while the engine is at work.

Duplicate ignition arrangements are sometimes fitted to the larger sizes of Gas Engines, so that in the event of one giving out the other can be put into operation without causing a stoppage.

CHAPTER XII.

HINTS TO BUYERS.

When placing an order for an engine, bear in mind the possibility of future repairs, and select a firm of standing and repute, who can send a representative with renewals at short notice upon emergencies.

The desiderata for Gas Engines are:—

1st. Good workmanship and finish.
2nd. Reliability and simplicity.
3rd. Economy and efficient governing.
4th. Reasonable price.
5th. Low cost of renewals.
6th. Easy get-at-ability.
7th. Substantial design (not necessarily of heavy weight).

Either put the ordering of a suitable engine into the hands of someone really competent to select the Gas Engine most suitable for your work, or make up your mind to thoroughly understand their principles and details. Do not take for granted all that makers' representatives say about their competitors' wares.

Do not hazard a guess at the power you think will do your work. Let a competent person take diagrams from your existing engine to find out what Indicated H.P. (horse-power) it is developing when under full load, and base your estimate of power upon that. Failing this, ask the different makers of your machines to state in writing the Brake H.P. each machine requires at its driving pulley, add to the total an ample allowance for friction of shafting, etc., and a margin for future extensions.

Do not use the term " Nominal " H.P. — it has no definite meaning. Always qualify the term H.P. as " Brake " or " Indicated," " Test," or " Working Load." See page 38.

Do not be misled by the term " Brake H.P." It should be further qualified as " Test Brake H.P." or " Working Brake H.P." There is usually 12 or 15 per cent. difference between these two terms and for sustained loads over long periods 20 to 25 per cent.

Do not be misled by the powers printed in makers' catalogues. They are usually maximum powers, and quoted as such. You must not expect to obtain the same result in daily work as is obtained by experts under test conditions. Remember also that the powers stated are for gas of good quality, usually for gas having a heat value of about 700 British thermal units per cubic foot. If upon enquiry at your gas works you are told that the gas supplied to your premises is lower than this, you must make a proportionate allowance from the makers' figures. It is sometimes possible, however, for the engines to give off the powers named in the lists, but then a greater consumption of gas will be needed to make up for poor quality.

Do not be misled by statements of gas consumption. To properly compare different engines in this respect the suggested form of enquiry given on p. 60 should be used. The figures thus obtained would have to be corrected for the quality, temperature, and pressure available on your premises, if you desired to go thoroughly into question of cost, but as the main idea is to select the most economical engine, the statements of makers, if on identical terms, will be sufficient for your purpose without further calculation.

Remember that a Gas Engine when overloaded will give off less power than it is capable of doing under proper conditions. The effect of overload is to diminish speed, which restricts the number of possible explosions. If an engine be designed to run at 200 revolutions per minute, 100 fires may be made when fully loaded, but if the overload reduces the speed to 190, the maximum number of explosions can only be 95.

To run a Gas Engine always at maximum load is unwise. Therefore an engine which gives a low figure for consumption under half-load and when running light is to be preferred.

An enquiry worded as follows should be used to obtain information from each maker upon identical terms, and thus to permit of a just comparison :—

" Please quote me for an engine capable of developing ——— Brake horse-power for driving ——— machinery, with the quality of gas as supplied by the ——— Gas Company (or by ————producer plant using ——— fuel). The load will be sustained (or variable, or intermittent, as the case may be) during a continuous run of ——— hours.

" With your estimate kindly send a statement of the amount of gas consumed per Brake horse-power per hour under 'full-test' load and 'half-test' load. Also the quantity when running 'light,' assuming in each case that the gas available is of 700 British Thermal Units heat value per cubic foot, that the pressure is 15-tenths when the engine is working, and that the temperature is 60 degrees F.

" Please enumerate the fittings and spare parts included in your price, and also state the diameter of piston and length of stroke of the engine you quote for, as well as the speed recommended.

" The price you quote must be inclusive of free delivery to ——— Station, ——— Railway. If packing cases are charged for, state allowance made upon their return to you."

CHAPTER XIII.

How a Gas Engine Works.

The principle of working most used is the "Otto" or "Beau de Rochas" cycle. Gas mixed with air in definite proportions (carefully adjusted to give the maximum strength of explosion with the utmost economy of gas) is admitted to the engine cylinder, and afterwards compressed to a degree which has been found most effective for the particular mixture for which the engine is adjusted. At the highest point of compression the mixture is brought into contact with a hot tube or electric spark, and an explosion follows, of such force that the impetus thus given to the flywheel, by means of a piston and crank properly connected, causes the engine to make two complete revolutions under all its load: the cycle of operations then causes another explosion. The action is similar to that of a cannon, the projectile being harnessed to a crank and flywheel to ensure its return to the proper position for being again discharged, to keep in motion the necessary gearing for automatically loading and firing at the proper moment, and also to provide a means whereby its power may be transmitted to other machinery.

As above stated, most modern Gas Engines are constructed to work on the "Otto" or "four cycle" principle, as follows :—

FIRST STROKE, OR OUT STROKE. The mixture is admitted, as the piston is drawn forward by the rotation of the flywheel, through the inlet valve, which is held open by suitable means throughout the stroke.

SECOND STROKE, OR IN STROKE. The inlet valve is closed, and the charge admitted is compressed by the backward movement of the piston, the temperature rising with the pressure until the stroke is completed.

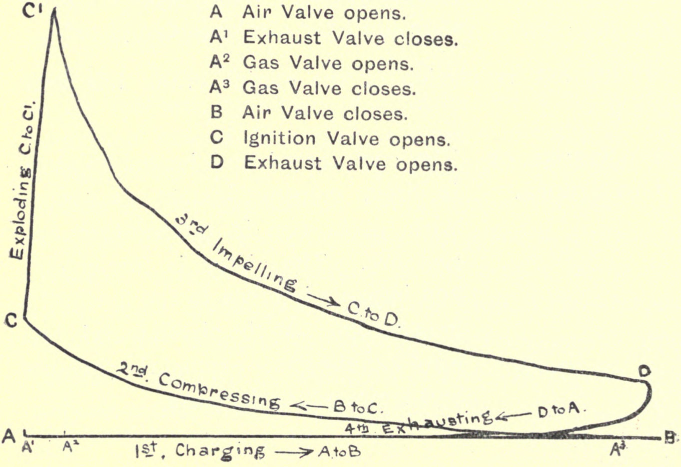
(Thus one revolution of the engine crank has been made.)

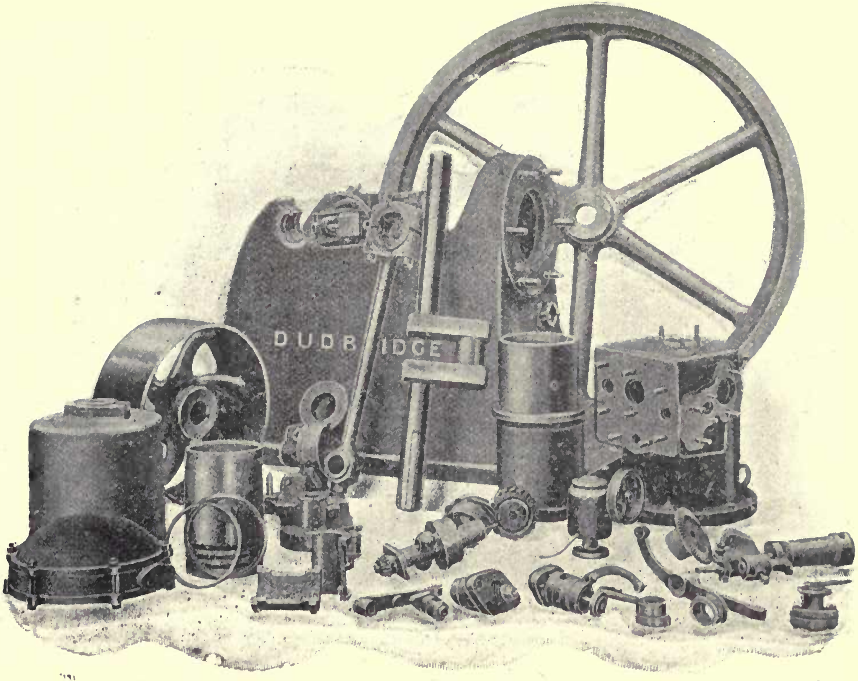
THIRD STROKE, OR OUT STROKE. The compressed and heated mixture is fired, causing instant explosion, with great rise in temperature and pressure. The piston is forced out, and impetus is given to the flywheel's momentum. As the piston travels forward and the gases expand the pressure and temperature decrease.

Fourth Stroke, Or in Stroke. The exhaust valve is opened by mechanical means just before the full completion of the third stroke, and opens communication to the atmosphere. As the piston returns into the cylinder the products of combustion are expelled through the open valve, thus clearing the way for a fresh charge.

(This completes the second revolution and the cycle of operations.)

The Indicator diagram illustrated here shows graphically the cycle above described.





The Component Parts of a Gas Engine.

PART II.

CHAPTER I.

NOTES ON THE GAS CONNECTIONS.

The gas meter must be of the "dry" type, of ample size, as specified by the Gas Engine makers.

The pipe between the meter and the gas bag should be, when the distance is but of moderate length, the next larger size to that between the gas bag and the engine. If the distance be great a pipe two sizes larger than the inlet to the engine should be erected for the major portion of the run. Bends only should be used for corners; all elbows should be tabooed, especially the square pattern. In short, no pains should be spared to make the way as free from restriction for the passage of gas as is possible.

On the outlet of the meter a main cock should be placed, so that the supply can be cut off from the engine connections when repairs or alterations are necessary. Another cock should be placed just before the inlet to the gas bag, and be used to cut off the gas to the engine whenever the latter is not at work. Between this cock and the outlet of meter a T-piece should be inserted, with a small branch to conduct the gas to the ignition tube; and at this point also it is advisable to place another branch, with a small cock or $\frac{1}{4}$-inch plug, from which a flexible rubber pipe can be taken to a gas pressure gauge when it is desired to obtain readings as to the pressure available when the engine is at work.

The gas bag is usually a cast-iron reservoir with a sheet of indiarubber forming one side. The rubber is clamped in position by a ring of metal, secured by screws or bolts. The bag should be of sufficient capacity to supply the engine with successive charges when working under full load and minimum gas pressure. The inlet to the bag is usually fitted with a contrivance called an "antifluctuator," to prevent any other branches taken from the main supply being affected by the suction of the engine. Occasionally the "antifluctuator" is a separate fitting, and in that case it is placed close to the inlet of the bag. Care should be taken when placing the bag in position to see that a space is left between the flexible rubber diaphragm and the wall, to allow distention to its fullest extent, and also to leave room for the hand to be inserted in order to determine whether the supply is sufficient or deficient when the engine is at work. If two pieces of wood about 3 or 4 inches square are secured vertically against the wall, and the bag bolted to these, this object will be attained.

The pipe between the gas bag and the engine should be as short and direct as possible, without a cock or anything which might throttle the supply. This length of piping should be put together with flanges, so as to facilitate removal when necessary; "connectors" or "long screws" can be used if preferred. If the gas inlet cock on the engine is not already provided with a small pet cock, a T-piece should be inserted close to the engine cock, with a small outlet fitted with a pet cock. This will allow the presence or absence of gas to be detected before a start is essayed. The existence of such a cock in the early days of Gas Engines would have saved many precious minutes, as there is little doubt that failures to start readily were due in numerous instances to the presence of air in the pipes, which had to be got rid of by continually rotating the fly-wheels by hand, when this means of testing was not provided for. Air in the pipes has caused a great number of people to condemn Gas Engines as unreliable.

The pipe supplying gas to the bunsen furnace heating the ignition tube should be taken from the T-piece mentioned above as being placed next to the main cock and between that and the outlet of meter. A cock should be placed close to the T-piece, to shut off the supply when the engine is not at work. In case of deficient gas pressure it is necessary—and in all cases it is desirable—to take this supply from a separate gas supply main altogether. When this is not possible a small rubber bag encircling a short length of perforated pipe should be fitted to act as a reservoir and thus to minimise possible fluctuations of pressure. This pipe, as indeed all those which from time to time have to be disconnected, should be fitted with flanges, to facilitate removal. A cock should be placed on the inlet to the bunsen burner, if not already provided by the Gas Engine makers, and when working this cock should be fully opened, and adjustments to the burner being effected by the screwed and tapered plug provided for the purpose.

When the engine is worked with producer gas the supply pipes must be of increased diameter, sufficient to pass the larger quantity necessary. If the engine is to work either with town or with " pressure " producer gas, the fittings should include larger bags than usual, fitted with cocks between the bags and the two supply mains. A separate " anti-fluctuator " is then provided for the town's main; the producer main does not require one. Adjustments of the gas and air inlets are necessary when changing from one source of supply to another. These adjustments are usually ascertained and unmistakably marked during the testing of the engine at the makers' works.

Gas Engines served with producer gas require special arrangements for igniting the charges. If towns' gas be not available for heating a bunsen furnace, the firing should be effected by electric spark, either from a battery of cells through an induction coil, or, better still, from a magneto-electric machine.

The use of a gas pressure governor fitted next to the outlet of the meter on the town supply main is much to be recommended. If this is set to the minimum pressure likely to be supplied by the gas company no variation of pressure will affect the working of the engine, and the adjustments to the gas inlet valve on the latter, when once made, will require no further attention.

CHAPTER II.

NOTES ON THE AIR SUPPLY.

The majority of Gas Engine builders use the base casting of the smaller engines as a reservoir from which the supply of air is drawn through a short length of pipe fitted with a screwed plug adjustment at the inlet to the air valve box. If, however, the engine is to work in an atmosphere containing solid matter in suspension, it is preferable to draw the supply from outside the building altogether, increasing the pipe's internal diameter if more than 15 or 20 feet long.

Some makers supply a cast iron box fitted with a screen of cocoanut matting, or similar material, to lessen the noise of the air suction, and for all engines over 30 B.H.P. in size the use of a separate air chamber is universal. The inlet to the chamber should be as free as possible, and the chamber itself of ample size, to suit the volume required by the engine. It should be fitted as close to the engine cylinder as is found convenient, with no cocks or throttling connections throughout its length.

While considering the supply of air, it would perhaps be as well to mention that the engine room should be well ventilated and kept as cool as possible. Both the exhaust chamber and the tank should be placed outside for preference.

When the water cooling tanks and exhaust box are fitted up inside the room, the place becomes almost unbearably hot in the course of a very few hours of work. The rise in temperature and impurity of the atmosphere naturally affect the amount of air taken in during the charging stroke of the engine, and, consequently, the mixing value is not then the same as when the engine was first put in motion. If after a time the gas pressure should also vary—as it frequently does—a very different mixture to that originally obtained may be entering the cylinder towards the end of the day, with a consequent variation of the power given out by the engine.

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CHAPTER III.

NOTES ON EXHAUST CONNECTIONS.

Within a few feet of the exhaust valve a large iron vessel is fitted to receive the sudden rush of burnt gases expelled through the exhaust passages by the returning of the piston into the cylinder. The size of this exhaust chamber should be sufficient to receive the volume discharged and to allow expansion to take place, with a consequent reduction of velocity. A pipe is taken from this box to the atmosphere as direct as possible, to avoid back pressure upon the piston, and the diameter of this pipe should be increased if more than 20 feet in length, unless two or more silencing chambers are used in series, when an increase in diameter is not so necessary. The pipe between the engine and silencing chamber should be fitted —similarly to the other connections—with flanges to facilitate removal when necessary. If the exhaust outlet on the engine be provided with studs, and studs are also fitted on the silencer, a pair of flanges with bolts and nuts should be fitted at a convenient joint between, otherwise the connections, once made, cannot be disturbed without a great amount of trouble. The silencing box should be fitted with a draining plug to get rid of any condensation that may collect in it.

The noise from the exhaust pipe is occasioned by the velocity with which the gases are emitted from the orifice violently disturbing the surrounding atmosphere. To lessen the noise it is necessary to reduce the velocity by allowing the gases to expand and to become cooler in the process.

The most efficient way, probably, is to cool the gases as they emerge from the exhaust valve by bringing them in contact with a small jet of water. Care should be taken to so adjust this jet that no excess of water is admitted to be ejected with the gases from the pipe. Only sufficient should be admitted to ensure all being converted into steam, which, passing with the gases, can rarely be distinguished. When this method is adopted the exhaust chamber must be connected to a drain, so that the condensed moisture can readily be discharged.

Where water for this purpose is not to hand, a series of iron chambers are used to allow of continuous expansion.

In some cases pits are built and filled with loose stones, large coke, or bricks loosely stacked—a cover, provided with a large outlet pipe, being placed over the mouth of the pit. Unless under careful supervision, these pits are rather risky. Occasionally, by some derangement, unburnt gas finds its way into the pit, and if, as is very probable, a miss-fire should then occur, there is every likelihood of a very nasty explosion. When this method is adopted the pits are usually lined with bricks or concrete, but an iron lining is much more to be preferred, as no disintegration can occur, and harmful results—such as when the exhaust valve, by sticking open, allows fine gritty dust from brick pits to be drawn into the cylinder—are rendered impossible.

Special silencing arrangements are sometimes made by enclosing a perforated pipe inside a larger one, or by inserting baffling plates between the inlet and outlet of a chamber of otherwise ordinary shape. For large Gas Engines the gases are sometimes led into a reservoir, somewhat like a small gas holder, placed in a tank full of water in such a way that the pressure of the expelled gases acting on the surface of the water causes the latter to be forced downwards, and to act as a cushion, receiving the force of the sudden pressure and allowing a steady and continuous flow to the atmosphere through a long vertical pipe. Sometimes the exhaust pipes of two or three engines working simultaneously, but firing at different intervals, are united in one large chamber, and from thence dispersed to the atmosphere by means of a long vertical pipe. Whatever method is employed care is necessary to avoid putting back pressure on the piston, and arrangements should be made to drain away all condensation that collects in the lowest portion of the connections.

CHAPTER IV.

NOTES ON WATER VESSEL AND CIRCULATION.

Owing to the great heat given out by the exploding gases it is necessary to provide means of keeping the cylinder cool in order to prevent any alteration in the proportion of the mixture drawn in and to ensure a constant strength and instant of explosion. For this purpose water is passed round the engine cylinder, etc., either by means of a pump or by the circulation of water by convection. Circulating tanks are more usually provided, and water is preferably fed to same by means of a ball cock, or, if no constant supply is to be obtained, by hand.

To ensure free and quick circulation it is necessary to exercise great care in fitting up the tanks and connections. The bottom of the tanks should never be lower than the centre of the engine crank. If they can be placed on a floor above so much the better.

The quantity of water in circulation should be sufficient to enable the engine to work throughout its longest run at no excessive heat. The bare hand should always be able to rest comfortably on the top of the cylinder jacket. If, by any means, insufficient water is in circulation, the water is likely to approach boiling point, and sediment is then deposited in the water passages, which in time become choked, almost entirely hindering circulation.

The ball cock on the supply pipe should deliver the cold water to the bottom of the tank by means of an internal division or pocket. The bottom pipe connection to the underside of the engine cylinder should be provided with a cock close to the tank, and, at the lowest point of the pipe, a T-piece should be placed and a drain cock fitted. By these means the pipes and engine passages may be emptied when frost is anticipated.

Care must be taken that no air can lodge in any part of the system of water pipes.

The return pipe should be taken vertically from the top connection on engine cylinder, and it must be given an upward tendency throughout its length. No " dips " or " levels " must occur, or the circulation will most probably be slackened, if not entirely impeded. All bends should be opened to more than right angles and have an easy curve. The return pipe should enter the tank within three or four inches of the top rim and fully one inch or more below the bottom of the overflow orifice. In case of hand-filled tanks three or more inches of cover will be more satisfactory and safe. The overflow is usually carried to the nearest drain by an open pipe.

In case the engine should be found to get too warm, the ball valve should be propped open and a constant supply run in. Another tank will usually overcome any trouble in this respect if lack of water storage is the cause of the overheating. In a good many instances a very great improvement has been effected by taking a second return water connection from the combustion end of the cylinder to the circulating tank. Occasionally, where the question of water economy is not of prime importance, a small quantity of cold water from the main is passed round the cylinder end, through duplicate connections, and run to waste, keeping the ordinary tank circulation going in the usual way at one and the same time. If a pond, canal, or river is at hand a small pump can be used to circulate the water round the cylinder.

CHAPTER V.

NOTES ON GAS ENGINE FOUNDATIONS.

Gas Engine makers provide a drawing showing, in plan and elevation, a room of suitable size to enclose the engine and its accessories, with suggested positions for the various fittings. These plans are usually drawn out with great attention to details; and a careful study, and comparison with the instruction card also provided, is well repaid.

The foundation shown is usually a block of concrete from 10 to 12 inches longer and wider than the base casting of the engine, and from 2 to 4 feet or more in depth, according to the size of engine and the nature of the ground.

A good foundation resting on a solid bottom is very essential, and care should be taken that this is obtained, even if it means considerable expense. Upon marshy land and on gravel foreshores it is necessary to sink piles to enclose a suitable area, and a thick crust of concrete, between cross timbers, should connect the engine foundation and the piles, so as to bind all in one mass.

The concrete should be a mixture of one part of cement to 4 or 5 of sand and fine gravel, with a finishing of, say, equal parts at the surface.

When ready to prepare the foundation the builders should mark out roughly the position, and excavate till a sufficient depth is obtained and a good bottom secured. A couple of planks should then be put across the hole, and upon them the wooden template of the engine base—which is usually lent by the makers for the purpose—is placed. This template must then be squared to the exact position, and the bolts and plates hung from it by means of the nuts, care being taken to leave sufficient length above the top of the template to ensure that the bolts will pass through the holes in the engine casting and to allow the nut in its final position to be screwed well home. Round the bolts should be placed 3-inch drain pipes—for the purpose of allowing free movement of the bolts until the engine has been erected, squared, and levelled. Instead of the drain pipes wooden boxes are sometimes roughly put together to answer the same purpose. Such boxes should be made wider at the top than at the bottom, so as to permit of easy withdrawal after the foundation has set. These holes are filled up with rich cement and sand after the engine has been squared and levelled, for which purpose a small " chase " should be left in the concrete bed round each bolt hole, to allow the semi-liquid " grout " to run under the engine base.

With brick foundations a good cement mortar must be used as a bond.

If neither brick nor concrete foundations be convenient, timbers, securely bolted and framed together, form a satisfactory bed, but the whole must be carefully keyed and all movement prevented, either by sinking the lower timbers well in the ground or by bolting through a solid flooring to a timber or iron bracing below. When placed upon flooring instead of the solid ground, vibration is sometimes set up, causing great annoyance. Every building appears to have a periodicity of vibrations peculiar to itself, and no general rule can be given to prevent this nuisance. The great thing is to place the engine in a corner between two strong walls or against the shorter end of the building ; and by experiment the particular speed which will not coincide with the vibratory periods of the building must be found. Sometimes running the engine faster than the usual speed is sufficient. Occasionally the engine base is bedded upon a thick pad of felt or upon two fibre mats placed (with the pile or faces together), with a plate of iron above and below—to distribute the weight equally over the surface. Such foundations, however, are usually springy, and allow the engine considerable movement, calling for special treatment as regards belting, etc. Isolating a block of concrete by a layer of sand at the bottom and at the sides has proved effective in many instances.

In any case the foundation of any engine should not be connected in any way with the footings of a main wall, or complaints of noise or vibration will undoubtedly follow.

CHAPTER VI.

NOTES ON SUITABLE ENGINE SITES.

In selecting a position for any engine underground pipes or drains should be avoided.

If it be possible the engine should be placed so that it can drive on to the main shafting by means of a belt that, when in motion, will have its tight or driving side underneath. The top side of the belt will then sag and increase the area in contact with the pulleys. The distance between the centres of the pulleys on engine and shaft should be of reasonable length, and the belts should not be led off directly overhead, as the tendency of the belt to hang off the under face of the bottom pulley would occasion a large amount of " slip." An open belt is much to be preferred to a crossed one, and should always be arranged for unless other circumstances prevailing absolutely preclude it. Whenever possible the belt should be led off at such an angle that the attendant is not hindered in getting at the relief lever, cams, etc., on the side shaft. When two belts are used, one on either side of the engine, they should not prevent the attendant getting at the working parts, as, in sudden emergency, much may depend upon the ease with which the gas valve can be reached and shut off. In case of the breakage of any belt fixed in such a position, it is a wise precaution to place the cock controlling the gas supply to the bag near a door or handhole, so that the minimum of risk is involved in stopping the engine. Otherwise it is very possible that the engine could not be reached —owing to the broken belt ends whirling round with the pulley—without endangering loss of life or limb. In such an event, of course, the engine could be stopped by turning off the gas at the meter, but this would be probably overlooked in the excitement of the moment.

A Gas Engine should preferably be fixed on a basement floor, but if this be impossible the advice of a competent man should be taken before deciding upon a position on an upper floor. It is not always the most convenient site that is the most suitable, as the probability of vibration, as well as the strength of support and walls, requires very special attention. Each building has its own peculiarities, and expert advice from both architect and engineer should be obtained before the final position is decided upon.

To avoid the use of fast and loose pulleys, shifting belts, and belt shifting gear, friction clutches are frequently fitted, and for heavy belts are almost indispensable. By the use of efficient clutches belting bills are greatly reduced owing to the absence of strain otherwise set up by the lateral movement given to the belt by the shifting forks. A friction clutch pulley fitted on the crankshaft allows the engine to be set in motion without belt friction, and this, in large engines especially, is an important matter.

CHAPTER VII.

HINTS TO ERECTORS.

Make sure of a solid bottom for the concrete or brick foundation to rest on.

Leave the foundation bolts loose in 3-inch round or square holes.

Let the bolts project a sufficient height above foundation.

Do not grout in the bolts before squaring and levelling up.

Do not use less than 1 part cement to 5 parts sand and fine gravel in mixing the concrete.

Study the makers' plan and instruction card before erecting the engine, and see that all necessary fittings have been sent.

In slinging be careful not to damage paint or bright work.

Measure up for lengths of pipes and put them on order, so that they will be to hand as soon as you have the engine on foundation.

Do not try to lift or move the flywheel without sufficient help.

Carefully clean all parts before putting together and wipe them with a clean oily rag. Take special care with bearings and piston, etc.

When placing the crank be careful that the marked teeth on the gear wheels coincide.

Block out the gas bag from the wall so that a hand can be put behind to feel whether the rubber diaphragm distends fully.

Fix the positions of gas bag, exhaust and air silencers, and water vessels before beginning to run the connecting pipes to engine.

Make provision, by flanges or connectors, to allow of pipes being easily disconnected for examination.

Lay all gas, exhaust, and bottom water connections in trenches covered with iron grating or plates. Do not cement them in the ground.

Keep the exhaust pipe 6 or 9 inches clear from all woodwork.

Fix exhaust box so that the drain plug can be easily withdrawn when necessary.

Allow for expansion of exhaust piping when heated; if long lengths use roller stays, and place exhaust silencer on 2 or 3 pieces of, say, 2-inch tube to allow of slight movement.

In a long length of vertical exhaust pipe insert a suitable drain pipe and cock at a convenient place to get rid of condensed moisture.

Take all connecting pipes the most direct route, and avoid unnecessary angles, using right angle bends where unavoidable. Use no elbows on any connections.

Carefully scrape round the interior of the pipe ends after screwing to remove all burrs.

Remove all interior scale from the pipes before screwing together. Use plenty of red lead in the joints, with spun yarn threads, to ensure gas and water tight connections.

Erect the water vessels on a stand the top of which is level with the centre of the engine cylinder.

Put water in the tanks as soon as possible, to test for leaks. Solder where necessary, but if only slightly " weeping," a little oatmeal helps it to " take up."

Before starting see that all lubricators are full and wicks and syphons in proper order, and oil pipes and passages clear.

Get rid of all sand, plaster, and builders' material generally.

Turn the engine round by hand to see that all is free before turning gas on.

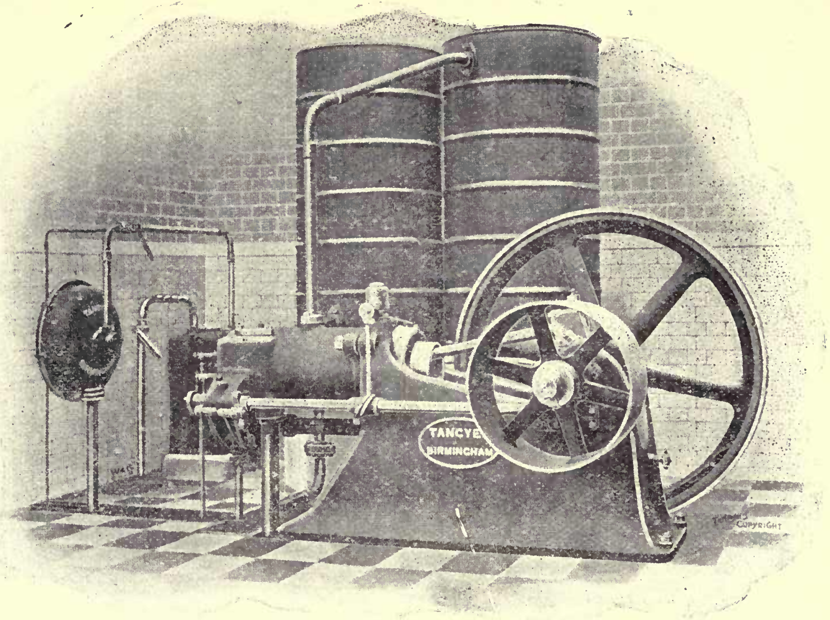
Expel all air from meter, gas pipes and bag, and make sure that the water is free to circulate.

Run the engine on slow speed when first starting up, and carefully watch all bearings and make sure that oil is reaching them.

Increase speed after first half-hour and run for an hour or two continuously if possible before putting on the load.

See that the fast and loose pulleys are in line, and fix the positions so that the belt is on outside portion of the engine pulley when the loose pulley is being driven.

The size of the engine pulley as recommended by the makers should be taken as of the minimum diameter desirable to give off the full power of the engine—with the particular width of belt—when working at the normal speed. The fast and loose pulleys should not be of smaller diameter, but if—owing to limited headroom, for example—this size be impossible, a wider belt must be used to avoid any diminution of the number of square inches of belt area in contact with the pulley.



GAS ENGINE AND APPURTENANCES ERECTED,
Illustration is designed to show how connections should be made.

PART III.

CHAPTER I.

Notes on Starting Gas Engines.

In the smaller sizes of engines, up to about 20 B.H.P., starting is effected by rotating the crank by hand, either by a handle made to fit round the shaft, and to engage one side of the keyway, or by pulling it round by means of the flywheel. In the sizes that can readily be started by one man, a handle is usually safer, as it is automatically thrown out of use directly the force of the explosion impels the engine at a speed faster than that imparted by the handle. When the flywheel is made use of to start the engine, some little skill is required in obtaining a speed of rotation brisk enough to overcome the compression resistance. If sufficient velocity is not attained the explosion is very apt to occur before the dead centre has been passed, causing the engine to reverse suddenly, and if any arms or legs have been used in putting the wheel in motion there is then every possibility of a nasty accident occurring. A smart man who has learnt the "knack," can start an engine of moderate size without difficulty. The feet should on no account be used to aid the wheel in getting up speed; if one man cannot overcome the resistance help should be given by another man pulling upon the wheel from the opposite side.

To effect a ready start it is necessary to pay attention to several little points. First of all the ignition tube should be at a bright red heat. The presence of gas at the gas valve should be tested by applying a light to a small cock on the supply pipe, fitted for that purpose by the erectors. If the flame is not of the unmistakable appearance which denotes the presence of gas, wait until all air has been expelled and gas obtained before trying to start. The next thing to do is to see that the crank is at the right position for starting, viz., the throw of the crank should be at its highest point on the firing stroke, all the valves then being closed. If the side shaft is not marked to denote this position, it is a good plan to rotate the engine in the reverse direction (with the gas shut off) until the resistance of compression is felt; this also makes sure that the valves are properly seated. The crank should be left in the starting position while the relief cam is thrown into gear by the lever specially provided for the purpose, and while the relief screw on the top of the ignition tube is slackened. If the engine is fitted with centrifugal governors the "sprag" should be also put into position. Then, and not till then, the gas cock should be opened, and the flywheel spun round at a fair rate.

The explosion should occur during the second revolution, and if any failure should take place, the gas valve should be shut at once and the cause found. Most probably, one of the minor points enumerated above has been forgotten. The flywheel should be turned round two or three times by hand, so as to pump out any remnants of the preceding unexploded charge through the exhaust valve. Another start should be made after giving attention to all the necessary details as mentioned above. Sometimes either the air or exhaust valve, or both, require regrinding on their seats, and this can be found out by rotating the engine in the reverse direction by hand (gas being shut off) and testing the amount of compression resistance, and noting whether such resistance gradually becomes less. The spindles of the valves sometimes want cleaning, a sticky deposit preventing the prompt closing of the valves. If the gas supply is at high pressure it is sometimes necessary to turn off the gas cock on the inlet of the gas bag, allowing the engine to make its first fire from a charge drawn in by the suction of the engine alone. If any difficulty is experienced in getting up sufficient speed to overcome the resistance of the compression stroke, the insertion of the blade of a pocket knife between the relief lever and its cam will be found of considerable assistance. Sometimes, after many futile efforts and precious minutes wasted, it is found that the failure to effect a start is caused by the supply of gas having been turned off at the meter. The presence of gas at the gas valve should always be ascertained. When a start has been effected, the relief screw on ignition tube should be closed and the relief lever put out of action.

For Gas Engines above 20 B.H.P. a pump is usually used for starting purposes. Varying with the size of the engine, a number of gas and air charges are forced in quick succession into the engine cylinder, the displaced air escaping through a relief cock at the top of the cylinder. When the required number of strokes have been made this relief cock is closed, and a few more strokes made at a slower rate. The mixture under this slight compression enters the hot tube, the more readily as the small relief screw on the top of the tube is slackened and allows a slight escape. An explosion follows, and the engine starts with more than enough energy to cause the full cycle of 2 revolutions to be made, thus bringing into operation the working parts which provide for the continuity of explosions. When the engine has started, and before the second "fire" can take place, a valve connecting the starter and cylinder must be shut down, a handle and quick-threaded screw being fitted to the valve for the purpose of completing this operation quickly. The piston of the starting pump should always be left at its inmost position when not in use. The relief screw on the top of the ignition tube should be closed, and the relief cam put out of gear in the same way as when the engine is started by hand.

For the largest sizes and for two or three engines of moderate size a small starting engine is often employed to charge the cylinders. It actuates a small air compressor, usually by means of an eccentric upon the engine shaft. Its mode of operations is similar to that described for the hand-pump starter, but instead of pumping a mixture of gas and air direct into the engine cylinder, air only is forced into a receiver at a suitable pressure. When the receiver is fully charged the compressed air is admitted to the engine cylinder by means of a hand starting valve, and gives sufficient motion to the main engine to enable it to take its charge of gas and air in the ordinary way, and gradually to attain its normal speed. The piston of the engine itself is sometimes used as a compressor while the engine is slowing down after a run.

CHAPTER II.

Notes on Failures and Defects.

The most common cause of failure to start, or of loud noises in exhaust connections, is the insufficient heat of the ignition tube. The tube should be a bright red heat. A little care in adjusting the gas supply to the bunsen flame will usually put this right. Sometimes the asbestos lining round the flame space requires renewing, and this can very readily be done with up-to-date engines.

Timing or ignition valves should be kept in good order and well seated.

Fracture of ignition tubes occasionally occurs, and a supply of spare tubes should always be at hand.

Dirty valves or valve spindles sometimes cause diminution or entire lack of compression, and loud noises in air or exhaust passages. The cure is obvious, and the valves should be rubbed down to their seats with a little flour emery. Coarse emery must not be used.

Presence of air in the gas main is often the cause of failure to start, especially on Monday mornings or after the engine has been standing idle for a day or so. Provision should always be made, by inserting a small cock on the gas supply pipe close to the inlet valve to engine, to allow the presence of gas to be ascertained before trying to start.

EXCESSIVE PRESSURE OF GAS forces more gas into the engine during the charging stroke than does the normal pressure for which the engine is adjusted, and the quality of the mixture being thus varied is occasionally too rich to be inflammable. The gas inlet valves are usually fitted with a throttling device, and by adjusting this by means of a screw and lock-nut the gas can be choked back, and the proper mixture obtained. When the gas pressure varies to a great extent during the day it is far better to fit up an efficient gas pressure governor on the gas main. This appliance is so constructed that whatever variation of pressure occurs at the inlet, the pressure beyond its outlet is kept to a constant figure. If such a governor, therefore, is set to work for the lowest pressure likely to occur throughout the day, no trouble arising from the gas service need be anticipated. In the absence of such gas governor it will be necessary to set the internal throttle in the gas inlet valve to the engine to suit the average pressure, and to effect further adjustment by means of the valve handle.

Occasionally the pressure of gas when the engine is standing is so great that it is necessary to turn off the supply to the gas bag until the engine has taken the first charge or so in order to effect a start.

Leaky Pistons prevent a proper amount of compression being obtained, and also let a portion of the exploded gases pass to the open end of the cylinder. The common cause is owing to the piston rings becoming embedded in carbon deposit and oily residue. The piston should be taken out and thoroughly cleaned, and the rings made free. After the engine has been at work some years it is often noticed that the results obtained after cleaning are not so good as before that necessary operation, the reason being that the piston and rings, being free, do not fit the worn liner so tightly as they did when the carbon deposit, etc., had increased the diameter of the piston by its presence under the rings. New rings should from time to time be fitted, and when necessary the liner should be rebored, and a new piston and rings of slightly larger diameter be supplied.

Irregular speed may be owing (1) to some derangement of the governor; (2) to the engine cylinder becoming too hot owing to bad water circulation; or (3) the ignition tube may not be hot enough to fire the mixture until a second charge has been mixed with the first, causing a THUMPING NOISE in the interior of the cylinder. This means, of course, a waste of gas, and should be remedied at once by proper adjustment of the bunsen furnace. Similar noises may also be caused by INSUFFICIENT SUPPLY OF GAS, and if this be the case it can usually be detected by the flabbiness of the gas bag. INTERNAL THUMPING may also denote early firing, due to too much gas or to excessive wear having taken place in the liner, allowing the piston to rock violently with the force of the explosions. It may be that the brasses in the small end of the connecting rod inside the piston are unduly worn and require adjustment. EXTERNAL THUMPING may be owing to the slackness of crank pin or main brasses, or to the key of the flywheel having worked loose.

Weak charges cause a LOUD REPORT in the exhaust pipe if slowly burning and still aflame when the exhaust valve is opened. Sometimes the charge is still alight when a succeeding charge is admitted; the new mixture is then at once fired and partly escapes through the open air valve. Too much gas may have a similar effect, as the mixture, being rich, may fire before the air valve has closed. The loud reports may, however, indicate that the valves are not properly closing, either owing to the presence of grit or because of the spindles sticking or springs becoming weakened. Occasionally damage is done in the exhaust pipe owing to previous weak charges having been expelled unburnt and exploded by the flame carried over from later explosions.

GRADUAL LOSS OF POWER may point to some blockage in the exhaust passage, either by carbon deposit or by condensation, partially filling the exhaust chamber.

LONG SERVICE GAS PIPES OF INSUFFICIENT DIAMETER occasionally cause stoppages which at first sight appear unaccountable. When the engine is working at full load, and the speed gets slower and finally miss-fires occur, it is a sign that the gas pressure has been reduced, and that the gas cannot flow into the bag quickly enough to supply the engine. It is a good plan in any case to take the small pipe for supplying the bunsen furnace from another service pipe if possible. Sometimes a second gas bag placed near the first overcomes the trouble caused by occasional very low pressures of gas. Engines can be adjusted to work with very low pressures if necessary, but at the expense of economy. In asking for supply from the gas company, it is advisable to ask for a service pipe suitable for maintaining at the gas bag a pressure of 1½ inches of water when the Gas Engine is taking its supply for full load, say —— cubic feet per hour, calculating on about

20 to 30 cubic feet per Brake H.P. per hour, according to size of engine.

DIFFICULTY IN STARTING is sometimes owing to the gas not having been turned on at the meter or gas bag, or to the relief handle not being put into operation, to insufficient compression owing to leaky valves or slackness of piston, or to the presence of air in the gas main. The attendant should make a practice of doing all the necessary details in a set order, and accustoming himself to that order. After a time the different movements will become quite habitual, and starting troubles will rarely occur.

WATER IN THE CYLINDER is sometimes the cause of failure to start. This may be owing to condensation collecting there—either of the valves being allowed to remain off their seats—or to the failure of the liner joint. The first may be prevented by always carefully leaving the crank at the bottom compression centre and withdrawing the plug at the bottom rim of the exhaust silencing chamber after each run. The defective liner joint calls for more expert attendance, and if the local repairers or the engine makers be called in they should not be allowed to call their work finished until the engine has been set to work and—with a plank under the flywheel—made to fire as at full load with the circulating water shut off, the object being to obtain utmost expansion of the bolts. When again cool the bolts must be screwed home to the utmost extent, the cylinder being removed from the engine for the purpose if necessary (see page 44).

EARLY FIRING may be caused by the ignition valve seat requiring re-grinding, or by too rich mixture. Sometimes it is caused by a previous charge (owing either to insufficient heat of ignition tube or too weak a mixture) still burning in the cylinder when the fresh mixture is admitted.

CHAPTER III.

HINTS TO ATTENDANTS.

Read all printed instructions sent out by the makers with the engine, and try to understand all about it, its method of work, and the use of the various levers and cams, and the exact portion of the " cycle " at which each act.

Get hints from the erectors, insurance company's inspector, or makers' representative, and ask for explanation of things you do not understand.

If you can spare the time, take readings of the gas meter before and after each day's run, and the number of hours worked, and any particulars about the amount of work done during the day. By comparing such notes it is often possible to tell when the engine needs attention by the increased consumption of gas when doing similar amount of work.

Read the notes about starting, and the proper sequence of operations as set down on a previous page, and try to follow the same routine in the order mentioned. You will then form a habit which will make starting failures extremely rare.

Attend particularly to the oiling arrangements. Keep all passages clear, and make sure that the oil reaches each point that wants lubrication. See that the worsted syphons are not twisted up so as to unduly restrict the supply. Keep all oil boxes covered up, but not so tightly that air cannot enter. Do not let any part be flooded with oil, and avoid waste. Use only good oil, and for the cylinder and piston it must be of special quality as selected and advised by the makers, or by some experienced person. After the oil has once passed the cylinder it may be filtered and used once more, but upon the bearings or other machines only. Ask your employer to buy a filter for this purpose; it will save money.

Do not run the bearings with loose caps; the brasses should be tightly screwed, metal to metal, so as to make a solid bush. If too much metal has been scraped away to allow of this without heating, a thin liner should be inserted between the joints and screwed hard up. Care must be taken not to adjust too tightly, or trouble will ensue. With Gas Engines especially, knocking due to loose bearings should be seen to at once, or the engine will go wrong, and possibly the brasses will need renewing rather than mere adjustment.

Do not interfere with any of the locked nuts or settings on the Gas Engine levers, or other adjustments. No alterations should be made for the sake of experiment. Once adjustments are varied it requires a very expert Gas Engine "tester" to put things right, as he has not only to get the engine to work, but to work *economically*, as when first sent out by the maker. If ever you are at a loss to know what to do, do not interfere, but call in somebody who does know.

If the engine gives out after working satisfactorily you may be sure that either it wants cleaning or that some of the connections or fittings are deranged—perhaps the pipes are getting choked up. *Whatever the cause it is most unlikely to require re-adjustment of the settings, so they should be left entirely alone.* Very often Gas Engines are blamed and time is spent in taking to pieces and replacing again, when all the while the trouble is not in the engine at all. Before you touch the engine you must be sure it needs attention, and know what you are going to do, and what the result will be. Do not experiment.

Keep all your tools together, so that you can always find what you want when you require it. Hang up your spanners tidily upon the wall.

Keep your spare parts clean and available at a moment's notice; as soon as you use a " spare," have it replaced.

Have a pair of piston ring pliers to aid in renewing rings. They are cheap, and save many breakages when carefully used.

When you see a defect remedy it as soon as possible; if beyond your powers, call your employer's attention to it and have it put right. Thoroughly overhaul the engine once a quarter and make careful examination of its condition. Do not put off such periodical attention if all seems right, as breakdowns may occur without warning, and cause great inconvenience and annoyance, and it is very probable that signs of weakness might have been noticed and defects remedied if the periodic overhauling had been done at the proper time.

Keep the engine room tidy and clean; do not allow oily waste to lie about, but have everything in apple-pie order, so that it may be inspected at any time.

Do not try to touch any portion of the engine while in motion; reserve the cleaning and wiping until the engine has stopped.

Never try to tighten or loosen nuts while the engine is running; the spanner may slip off and your own balance thereby be upset, with serious results.

When starting, do not put your foot on the flywheel for fear of back-fires. For the same reason be careful that the compression centre is overcome by turning the wheel smartly, as, if not, the explosion may send the wheel back in the reverse direction and pull you over the top of it.

If you suspect a leaky gas pipe smear it with soapsuds or oil; bubbles will then form and disclose the weak spot.

In winter weather turn off the cock on the bottom water connection and drain the engine cylinder and pipes; make sure that the cock is turned on again when next setting to work. A light is sometimes left burning under the cylinder instead of draining the pipes.

Feel the external surface of the cylinder from time to time to know that it is not getting too hot. If you cannot bear the palm of your hand against it, run in cold water to the tanks.

When ordering any broken or worn out part do not give it a name, as possibly that particular portion is known by an entirely different word by the makers, and confusion may arise. Make a rough sketch of the part, giving all important dimensions, and quote also the number of the engine (usually stamped upon the bed or name-plate). Merely quoting the number of engine is not always sufficient, as in the course of years many details are altered in size and design, the changes being in some cases so gradual that a difficulty is experienced by the makers in knowing exactly how any particular engine is fitted. A sketch, therefore, however rough, is often of great advantage, and the means of preventing vexatious delays through insufficient verbal description.

Allow nobody to tamper with the engine, and be chary in accepting a man at his own estimate, who boasts that he "knows all about Gas Engines."

Porcelain or "clay" ignition tubes require daily attention to see that they are tightly clamped in position. No looseness when cold must be permitted.

Do not put any heated porcelain tube upon any cold metal or stone, or it will split. Always put it down upon a piece of wood or sheet of asbestos, or piece of clean waste.

Do not look down the chimney oftener than absolutely necessary, in case at that very moment it should split or burst. Always turn off the engine gas cock while you are examining the heat of the tube.

When taking the engine apart for cleaning, make sure that the gas has been turned off at the meter, and all gas bags and pipes emptied of gas. *The exhaust valve cover should be removed, and the flywheel turned round several times by hand* to expel all gas, before any naked lights are held near for illumination of interior parts, even if the engine has for some time been standing idle. This is very important, as a very nasty accident may occur from the omission of this precaution.

When cleaning the engine, uncouple the big end of the connecting rod from the crank, while the latter is at its highest point. Then carefully let the throw of the crank turn to its lowest point, meanwhile holding the end of the connecting rod to prevent it from suddenly falling. Pull the piston out at once—lowering it carefully on to a block of wood placed for the purpose—and scrape the " back end." Make the rings free and see that they all fit round their pegs. Before putting back the piston take the valves out, clean and re-surface the seats by grinding with a little flour emery, slightly oil the valve spindles, and before putting in place insert a light through one of the valve seats and look through the open end of the liner to inspect the condition of the interior as regards cleanliness and wear. If the piston rings require renewing, change the back one first, as this always gets the most wear and should be a good fit. In entering the piston into the liner turn it so that the pegs for the rings are on the top; it will then be easier. Be careful not to rotate the crank shaft while the connecting rod is lying upon it, or the chances are that it will jam the rod against the top of the liner, and probably break a piece off the portion that projects through the bed casting.

SUPPLEMENTARY CHAPTER.

"SUCTION" GAS PRODUCERS.

In the early part of this book reference is made to Gas Producing Plants generally, but owing to the great interest of power users in the latest developments in this branch of engineering, a few notes are given here to explain the advantages, action, and application of "Suction" Gas Plants.

The principle of Gas making in "Suction" Gas producers is similar to that of the older form of "Pressure" plant. Air and water vapour (in "Suction" plants) or steam at a pressure above that of the atmosphere and sometimes superheated (in Pressure plants) is made to pass through a mass of incandescent coal or coke. The oxygen in the air and water combine chemically with the carbon in the coal or coke, forming, principally, carbonic oxide and, partly, carbonic dioxide. The hydrogen in the water is set free and enriches the mixture. The nitrogen in the air is also set free, but—as also carbonic dioxide—possesses no "power" value. The resultant gas has a calorific value of about 150 British Thermal Units per cubic foot, as against 550 to 700 British Thermal Units in Coal Gas supplied by " town " mains. The Producer Gas is not as dangerous as " town " Gas as regards risk of explosion, but it is necessary to lead all vent pipes from dwelling places, etc., as the carbonic oxide (or carbon monoxide), being highly poisonous, threatens asphyxiation to human beings.

" Pressure " plants consist of :—

- (*a*) Small Steam Boiler.
- (*b*) Generator with Feeding Hopper and Steam and Air Injector.
- (*c*) Hydraulic Box or Water Seal.
- (*d*) Coke Scrubber.
- (*e*) Sawdust Scrubber.
- (*f*) Gas Holder.
- (*g*) Governing Gear (controlling quantity of steam to Injector by relative position of Gas Holder Dome).

" Suction " Plants consist of :—

- (*a*) Generator with Water Heating Arrangement.
- (*b*) Hydraulic Box or Water Seal.
- (*c*) Coke Scrubber and Cooler.
- (*d*) Expansion Box.

The absence of the boiler and Gas holder demands less floor space for a " Suction " plant than for a " Pressure " plant. No special permission has to be obtained from the local authorities.

The air and water vapour are allowed to reach the bottom of the incandescent fuel at atmospheric pressure and the suction of the engine alone causes Gas to be made. It is, therefore, impossible for the poisonous Gas to leak from the system. The Gas is made at less than atmospheric pressure and the hydraulic box or water seal prevents diffusion when the plant has stopped working. When starting a fan is used in order to create a draught to quickly kindle the fuel. At such times the vent pipe is open, carrying away, at first, smoke and, afterwards, very poor Gas—similar to that given off from house fires. As soon as the fuel is properly incandescent, water vapour is allowed to enter with the air. The fan is kept in motion to force the Gas through all the connecting pipes to the engine, and during this period the plant is under slight "pressure." As soon as the trial cock at the engine notifies the presence of burnable Gas the engine is put to work, the fan is stopped, and, immediately, the Gas is at less than atmospheric pressure. From 15 to 20 minutes is usually taken up in the necessary operations for starting.

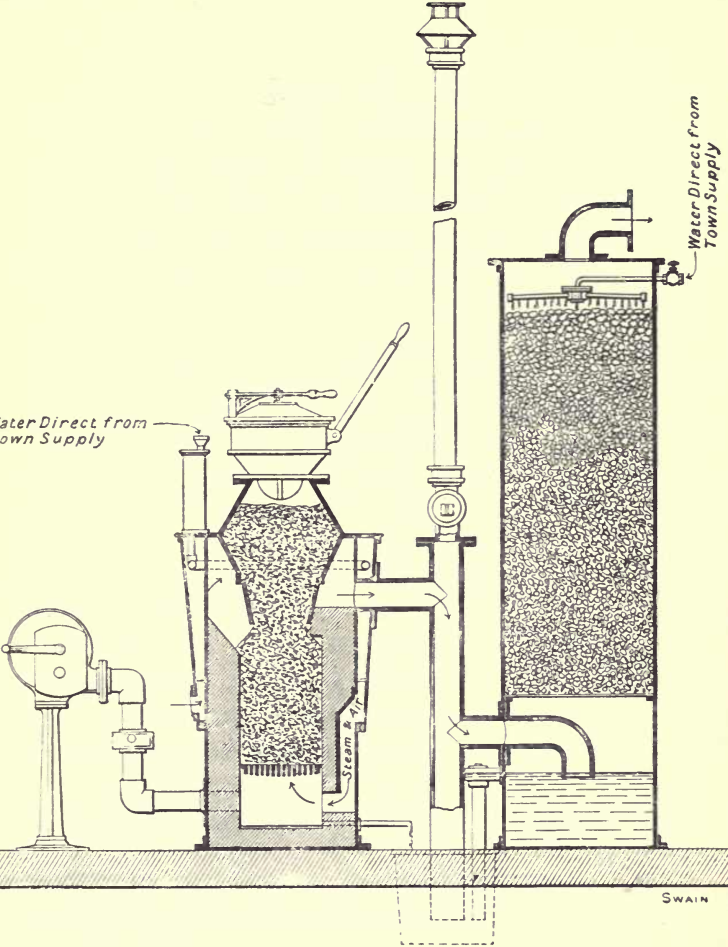
When stopped, the water seal prevents the Gas in the scrubber and connections leaking back and being fired by the hot fuel in the generator—then open to the air only.

The vent pipe is opened directly the engine is "shut down" and the gases given off—similar to those from a house stove—escape to the open air. The fuel gradually deadens, but is easily brought to a state of incandescence next day by a few minutes' " blowing up " by means of the fan.

The details of " Suction " plants vary with each maker, and in another handbook in this series the different types are illustrated and compared. A section of one of the most modern installations is given here, and from the annotations the various component parts and their functions will be recognised.

The fuel most suitable for use in " Suction " Gas Plants is Welsh anthracite. This coal has 91 to 92 per cent. of carbon in its composition. It contains very little sulphur and tarry constituents. It does not cake together to form "clinkers," and leaves but 1½ to 2½ per cent. of ash. The most suitable size of coal is "peas"' from ⅜ to ¾ inch cube. Coal of this size presents a large surface of incandescent carbon to the air and water vapour and yet is free from small " dust," which would tend to restrict the passage of the Gas through the bed of fuel.

In the absence of cheap supplies of anthracite " peas," washed Gas works coke, in pieces of 1 to 1¼ inches cube, can be used. The fuel consumption is not then so low as


Water Direct from Town Supply
Water Direct from Town Supply
Steam & Air
SWAIN S

with anthracite, the relative figures being 1lb. of anthracite, and $1\frac{1}{4}$lbs. of Gas works coke per Brake H.P. per hour.

The Generator is lined with fire bricks, which require renewing from time to time, say every 9 to 12 months. The Scrubber is filled with washed Gas coke about 4 inches cube, and requires to be cleaned out and refilled with fresh coke about every six months.

The Producer Gas being less purified than "town" Gas, attacks brass and copper. The Gas inlet valve, therefore, is all of cast iron. This valve must be removed every day or two to be cleaned from deposit, as some tarry matters are carried over to the engine, especially if no sawdust scrubber be used in addition to the coke scrubber. It is advisable that electric ignition with a variable timing device be fitted to the engine. The Gas valve should admit of quick variation and the supply of air should also be readily controlled by a throttle valve.

All pipes and connections should be arranged so that the same can be easily cleaned when necessary.

The advantages of Gas Producer Plant generally may be set forth as follows :—

A Gas Engine of a well-known make served by a "Suction" Gas Producer has, for six hours continuously, developed 21·11 Brake Horse Power under test conditions at the makers' works, with a consumption of coal (anthracite "peas") as low as .785lbs. per Brake Horse Power per hour. In practical work most makers guarantee a consumption of 1lb. of Welsh anthracite "peas" per Brake H.P. hour or **1.15 lbs. per Indicated H.P. hour**—a usually more convenient standard of comparison, being easily measured. A very high class Steam Engine requires at least 15lbs. of steam per Indicated H.P. hour; a very good boiler, carefully stoked, can evaporate as much as 10lbs. of water per 1lb. of good Welsh coal, equal to a consumption of **1.5lbs. of fuel per Indicated H.P. hour.** The same money value for 1lb. of coal is involved in each of these illustrations, as with inferior coal less water would be evaporated per lb. of fuel consumed in the boiler furnace.

The saving in fuel cost in practical work is therefore at least .35lb. per Indicated Horse Power per hour—but this is not all.

The Gas Producer Plant consumes for evaporating and cooling purposes about 2.3 gallons of water per Indicated H.P. per hour, and this may be of any degree of hardness. without interfering with the efficiency of the generator to an appreciable extent. A Steam Boiler demands at least 3 gallons of water per Indicated Horse Power per hour—very frequently much more—and the quality must be such that but little scale is formed in the boiler. "With water of 15 degrees of hardness a 100 H.P. boiler evaporating 3 gallons of water per Indicated H.P. hour, and working 10 hours a day, would have over 1 ton of deposit in the year to be cleaned out at intervals." It is also stated (by Dr. S. Rideal in "Water and its Purification") that a deposit of scale one-sixth of an inch thick inside boiler plates necessitates the use of 16 per cent. more fuel; scale one-fourth of an inch thick increases this percentage to 50; and if the boiler be neglected until the scale is half an inch in thickness 150 per cent. more fuel is required than when the plates are clean. The lower cost for water, and the savings made by obviating the cleaning-out of boilers, and the purchase of water softeners, etc., are therefore other points in favour of "Suction" Gas Producers.

A further advantage over Steam Engine and Boiler is in the cost of attendance. A Steam Boiler requires constant and careful stoking to maintain a steady supply of steam at uniform pressure and especially when serving an engine under varying loads. A careless attendant can waste more fuel in a Boiler furnace than is ever possible with a Gas Producer Plant. The generator of a "Suction" Plant requires recharging about once in every three hours, and the whole operation of charging and clearing the fire need only occupy a man about 5 minutes. The rate of Gas-making is entirely controlled by the load on the engine, the heavier the load the more the fire is quickened and the more freely is Gas made, and, by intelligent care, the state of incandescence and depth of fire can be made to suit varying loads. Naturally, with light loads, special attention has to be paid to see that the fire is kept at a proper state of incandescence, as, owing to the fewer suction strokes being made by the engine lessening the " draught," the conditions are not the same as when full loads are being carried.

INDEX.

PAGE

Air in Gas Pipes ... 70, 96
,, Pipes 73
,, ,, Explosions in ... 103
,, Silencing Chambers ... 73
Attendance, Cost of 33
Attendants, Hints to 107
Belts 86, 88, 92
Bent Crank Shafts 49
Blast Furnace Gas 28
Brake Horse-power 39
Centrifugal Governors... ... 52
Circulating Tanks ... 35, 79
Circulation of Water ... 35, 79
Cleaning 113
Clutch-Friction 88
Cost of Attendance 33
,, Cleaning 30
,, Erection 36
,, Producer Gas ... 27
,, Towns' Gas 24
,, New Liners 31
,, Renewals 31

PAGE

Cost of Repairs 31
,, Up-keep 30
,, Water 35
Crank Shafts 49
Cycle of Operations 65
Cylinders 43
Difficulties in Starting 97, 105
Dirty Valves and Spindles 97, 100
Early Ignition 103, 106
Electric Motors 9
,, Ignition ... 58, 72
Engine Room Ventilation ... 74
Erection, Cost of 36
Erectors, Hints to 89
Exhaust Pipes 75
,, Pits 77
,, Silencers 76
Failures to Start 97
Fixing, Cost of... 36
Flywheels 50
Foundations 82
Friction Clutch 88

INDEX—*continued.*

PAGE

Gas Bag 69
,, Blast Furnace 28
,, Connections 68
,, Consumption ... 25, 61
,, Cost for 24, 27
,, Engines v. Electric Motors 9
,, ,, ,, Oil Engines ... 16
,, ,, ,, Steam Engines 19
,, Heat Value 24
,, Inlet Valve ... 70, 101
,, Meter 68
,, "Mond" 28
,, Pressure 101
,, Pressure Gauge 69
,, ,, Governor 72, 101
,, Producer 71, 115
,, Supply Pipes 68
,, Towns' 24
Gauge, Gas Pressure 69
Governors, Engine 52
,, Gas Pressure 72, 101
Gradual Loss of Power ... 104
Heat of Ignition Tube 55, 100
,, Value of Gas 24
Hints to Attendants 107
,, Erectors 89
,, Purchasers 59
Horse-power, Actual 39
,, ,, Brake 39
,, ,, Effective ... 39

PAGE

Horse-power, Electrical ... 9
,, ,, Indicated 38, 40
,, ,, Nominal... ... 40
,, ,, Test Load ... 40
,, ,, Working Load ... 40
How to Clean 113
Ignition, Electrical ... 58, 72
,, Timing Valves 55, 100
,, Tubes 55, 112
Insufficient Gas Supply 103, 104
Internal Thumping 103
Irregular Speed 102
Joints 91, 105
Junk Rings and Pistons ... 46
Knocking Noises 103
Leaky Pistons 102
Life—Years of Service ... 32
Loose Liners 31, 45, 114
Loud Reports 103
Magneto-Electric Machine 58, 72
"Mond" Producer Gas ... 28
Nominal Horse-power ... 40
Oil Filters 108
,, Gas Plants 28
,, Lubricating ... 48, 108
Otto Cycle 65
Pipes, Air 73
,, Exhaust 75
,, Gas 68
,, Water 79

INDEX—*continued.*

PAGE
Piston 46
,, Rings 46
,, Ring Pliers ... 47, 110
Pits for Exhaust 77
Powers 38, 60
Pumps for Starting 98
,, ,, Water Cooling ... 81
Purchasers, Hints for 59
Renewals 31
Repairs... 31
Shafting 41, 42
Silencers, Air 73
,, Exhaust 76
Sites, Suitable... 86
Slotted Cranks 49

PAGE
Starters... 98
Starting Difficulties ... 97, 105
Suction Gas Producers 29, 115
Tanks 35, 79
Tests 39, 40
Thumping Noises 103
Tubes 55, 112
Valves, Dirty 97, 100
Ventilation 74
Vibration 84, 87
Water for Exhaust 76
,, Tanks ... 35, 79
,, in Cylinder ... 105
,, Vessels ... 35, 79
Working Horse-power ... 40

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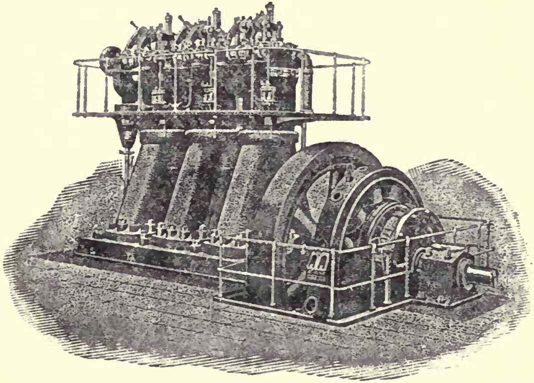

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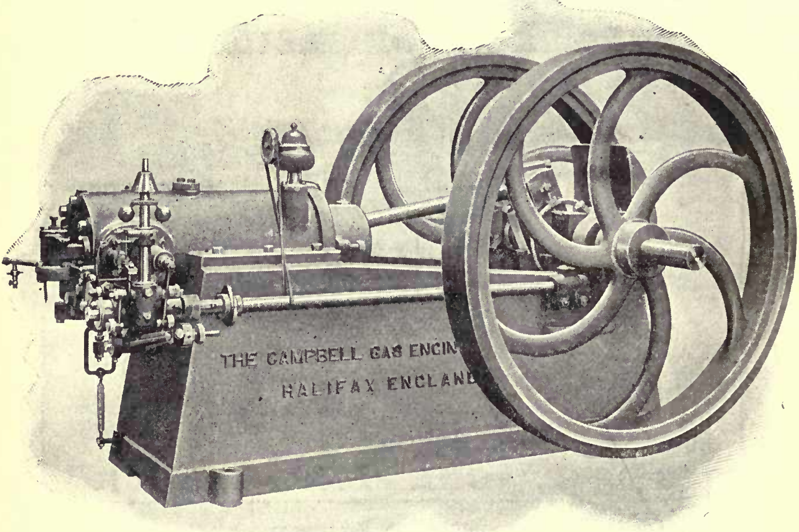

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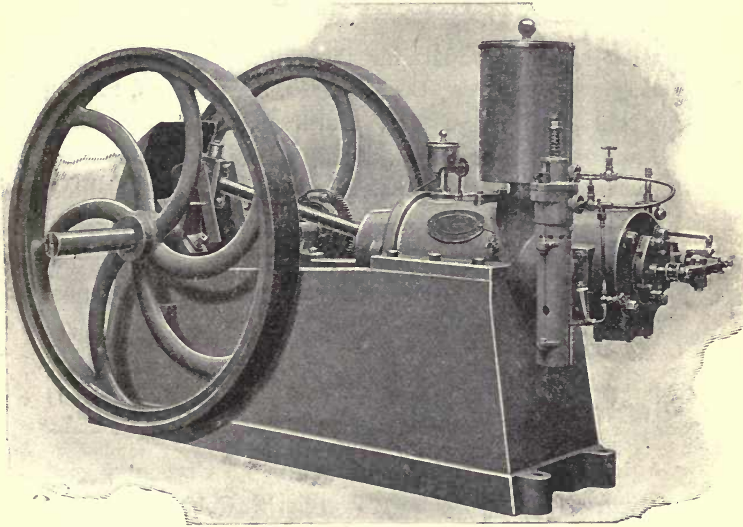

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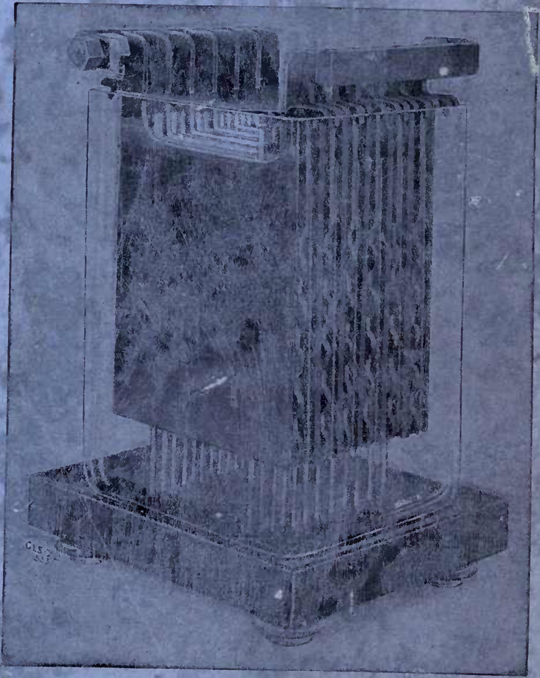

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